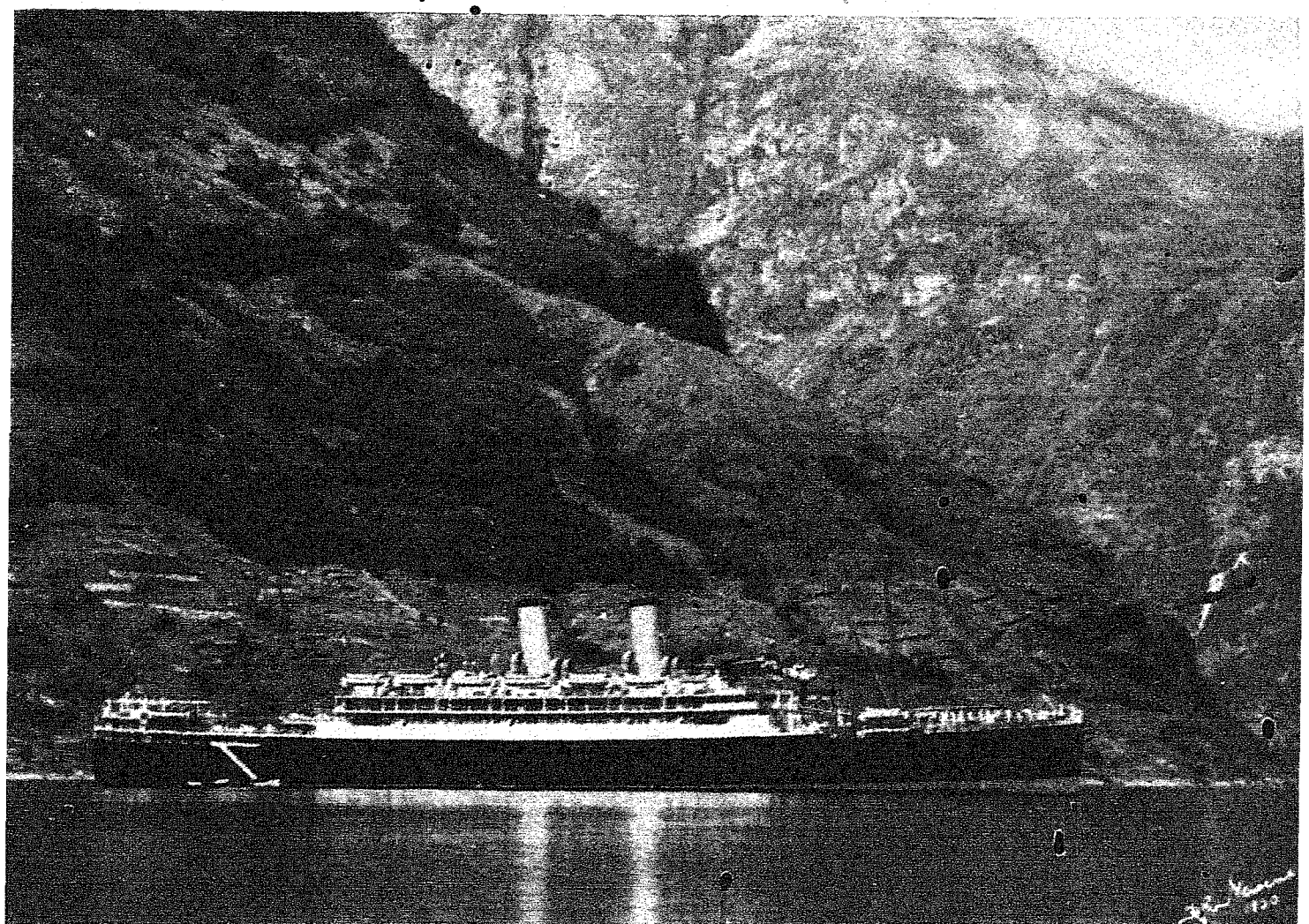

COLOUR PHOTOGRAPH OF R.M.S. *ORFORD* AT MEROK, NORWAY

(Negative taken with repeating back)

The Technique of Colour Photography

BY

FRANK R. NEWENS
F.R.P.S.

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DEDICATION

To the many good friends to whose constant encouragement and help is largely due what little success I have attained in colour photography, I dedicate this book.

Among so many it is, perhaps, invidious to mention names, but to Miss A. B. Warburg, Miss V. K. Blaiklock, Mr. F. J. Tritton, and other members of the Colour Group of the Royal Photographic Society, I owe especial thanks. To Mr. S. Manners, the inventor of the Raydex process, I owe my introduction to the fascinations of colour printing; to Mr. W. M. Rouse, of the Autotype Company, permission to include the working details of Dyebro and Carbro; then last, but not least, to Mr. George E. Brown, Editor of the *British Journal of Photography*, in common with every colour worker in this country, I owe a good deal more than I can express in words.

F. R. N.

PREFACE

When I was approached by the publishers of this work it was with some diffidence that I agreed to write a book upon the Technique of Colour Photography. This diffidence was the outcome partly of a wide and peculiar knowledge of my own shortcomings, and partly of the natural feeling that so much has been written on the subject already, that one wonders if it would be at all possible to deal with it afresh and in a fashion which would make the book fill some niche not already occupied by works of a similar nature. Then, too, at the request that a certain amount of theory should be incorporated —I was aghast at the thought! For the subject covers such an enormous field that even were I qualified to write thereon, how *could* I condense it so that the average photographer would consent to wade through it?

"Average photographer!"—those words brought to my mind the person who usually wishes to start upon colour photography. Believe me! it isn't the well-known pictorialist, nor the eminent scientific photographer who *starts* upon colour photography. It is the average photographer, the man or woman who, seeing some scene in nature ablaze with colour, sighs for the knowledge and means of reproducing those beauties by means of the photographic plate. He, or she, isn't particularly interested in *why* it is possible, but rather in *how* it is possible. And he, or she, more particularly she, perhaps, will only read or listen to theory in so far as it may be of actual assistance in the work itself. This characteristic —may I breathe it—is by no means the prerogative of the amateur.

So, thought I, it shall be for the average photographer—for him or her who has dabbled a little in the joys of photography, and who will appreciate being put on what seems to me the surest road to success; and who for the sake of that success will perhaps consent to forget some of his or her little idiosyncrasies of working, and start afresh on the lines laid down herein. I lay great stress on the actual details of the methods recommended, because unimportant as they may

appear at times to be, they are the outcome of many years of painful experience and thought, devoted to the avoidance of snags which go to make all the difference between failure and success. It is the little things that spell success in the practice of colour photography.

And theory! well, since of necessity at times some knowledge of theory is wanted, in this I have endeavoured to bring in what I feel *is* necessary, and I have tried to put it into some sort of sequence which shall show its bearing upon the problems that will have to be faced by the worker. Therefore in planning the book I have had in mind not what the reader *ought* to start with, but rather what I know he *will* (hence the placing of the chapters on colour printing before those on colour transparencies), notwithstanding that he may lessen his chance of success by attempting to run before he can walk. For run he will, so I have tried to help him. Who ever heard of the advice to start photography with a stand camera heeded by the budding photographer!

I have based what theory I have introduced upon the questions I have been asked during the course of a good many years of demonstrating and lecturing upon the joys and sorrows of colour photography. If the more advanced worker who has previously delved into this sphere thinks it somewhat elementary, may I remind him that it is designed for the beginner, and similes which may appear to partake a little of the schoolroom are helpful even to minds which left such scenes behind them a good many years ago.

It has been a source of wonderment to me on many occasions, when I have realized what children we are when introduced to a subject with which we are unfamiliar. The accomplished and cultured musician may have a taste in snapshots which will give the pictorial photographer the megrims, whilst the pictorialist's taste in music would possibly cause the musician to squirm in his shoes, though doubtless in the majority of cases each would be too polite to inform the other of the state of affairs. This, too, I have borne in mind, and if perchance the manner of it is not to the taste of some readers, why! in such matters this is still a free country, and the right to skip has not yet been placed under the ban of the Home Secretary.

FRANK R. NEWENS.

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THE TECHNIQUE OF COLOUR PHOTOGRAPHY

CHAPTER I

Principles of Colour and Colour Photography

Historical Introduction

It has been the desire of photographers since the earliest days of photography to be able to record, by means of the camera and photographic plate, not only the contours and modelling, the high-lights, half-tones, and shadows of the object photographed, beautiful though these may be, but also the actual colours of nature itself.

The starting-point of photography may be ascribed to the idea born of the brain of Thomas Wedgwood (the son of the most famous of English potters) which suggested to him the possibility of recording objects by the action of light, and which was described by Davy in the *Journal of the Royal Institution* in 1802. A period of some thirty years passed by before, in August 1835, the first authenticated photograph was taken, that of a window in Lacock Abbey, by William Henry Fox Talbot. This is generally considered to mark the birth of photography as we know it to-day, employing both a negative and a positive. Daguerre invented his process about the same time, communicating " his perfected

process of obtaining permanent pictures by sun action", as it was somewhat quaintly described, to the French Academy in 1839.

Curiously enough, an almost similar period of time elapsed before any new idea emerged to elucidate the problem of photography in natural colours. For it was in the year 1861 that the great scientist Clerk-Maxwell enunciated his theory that all the colours in nature could be matched by the proper admixture of three primary colours selected from the spectrum —red, green, and blue-violet. Upon this discovery it may be claimed that all subsequent attempts, successful and unsuccessful, at colour photography have been based, with the possible exception of the process invented by Professor Lippmann, a process of great scientific interest, but unfortunately of no practical value.

Speculative details of methods of employing Clerk-Maxwell's discovery were given by Ducos du Hauron about the year 1868, but, lacking suitable materials (the panchromatic plate was unknown in those days) and receiving but scant encouragement from the French societies devoted to the interests of photography, du Hauron was unable to put his theories into successful practice. This was first done almost simultaneously by two men working upon the lines indicated by du Hauron, namely, Professor Joly of Dublin, and MacDonough of America. Joly is generally looked upon as being the first actually to produce results, but MacDonough forestalled Joly in patenting his shellac-grain screen-plate process in 1892, two years before the latter brought his fine screen plate into public notice. Shortly after this the brothers Lumière invented their starch-grain process, but it was not until the year 1907 that this process, which has since proved to be one of the most successful of transparency colour processes, was placed upon the market. This was followed in 1913 by the Paget process, which was a modification of an earlier process known as the Thames screen-plate process.

The year 1924 saw the reintroduction of the Agfa process (it was first produced in Germany during the Great War in 1916), which was soon followed by the "Lignose" colour screen film, the first colour process upon roll and flat film to be placed upon the market. This, though it produced some exceedingly fine results, was not long in existence, as the difficulties of working the film in the roll were considerable, and it was finally absorbed by the Agfa Company and taken off the market.

This brief outline of the history of some of the best-known colour processes takes no account of the many methods connected with what are known as the subtractive processes, i.e. those processes which are mostly concerned with the production of print upon paper. Few of these, however, have reached a stage of simplicity that would be attractive to the average photographer; and since it is with such processes as have reached that stage of development, and have survived, that this book is to deal, it will suffice to defer mention of them to a later page.

Principles Underlying Colour Photography

Before describing in detail any of the above-mentioned processes, it is desirable that some idea of the principles underlying the practice of colour photography should be given, in order that the reader may understand what is meant by "colour", and have some notion of the physical phenomena with which colour is associated, so that he may be provided with a moderately clear idea of the problems involved in his labours. It is hoped that this knowledge will not only make his hobby more interesting, but will help him in its actual practice, since it should to a very large degree enable him to see the reason for doing certain things and for avoiding others which are only a waste of time. In colour photography suggestions are apt to present themselves which are superficially promising, and upon which much time and labour may be expended, but a knowledge of the theory underlying

practice will put the reader in a position to discard many of these suggestions at once, as impracticable and valueless. It is doubtless true that such knowledge is not essential to successful practice, and the following notes may be passed over if the reader so desires; yet it will frequently be found of great assistance if a clear understanding of the underlying principles is possessed by the worker.

Everyone to-day is aware that white light, such as sunlight, is not quite the simple " oneness " (if so it may be described) that perhaps as children we were apt to imagine it to be. The rainbow, which we see when the sun's rays fall upon the raindrops of a distant shower, tells us that. We know that the light of the sun, in some remarkable fashion, can be split up into those beautiful colours, which we see in even greater intensity and brilliance, thrown upon the ceiling or wall, when a narrow beam of sunlight falls upon the bevelled edge of a mirror, or the cut-glass stopper of a bottle, though possibly we may not have speculated upon, or even realized, the connexion between these phenomena and colour photography.

It is common knowledge, of course, that a similar result can be produced at will by passing a ray of light through a diffraction grating, or a glass prism, when this same band of colours, the spectrum as it is called, can be seen emerging from it. That these colours are really the original beam of light in an altered form can be proved by placing a second prism, of similar angles, in reversed position, against the first, when the light will be seen no longer in its component parts, but proceeding from the second prism in the form in which it entered the first.

When one contemplates the enormous variety of tints and colours, the statement that any colour in nature can be matched by the admixture of three only, seems at first sight a somewhat staggering one to make. It will, however, be easier to comprehend if the question of what is meant by "colour" is gone into a little more deeply.

For the moment the "wave" theory of the nature of light will not be dealt with, though at a later stage it will be necessary to delve a little into this rather more complex side of the problem.

Nature of Colour

When we see a coloured object, be it a flower, or a brightly coloured piece of silk, or what not, we know that no matter how brilliant the colours may appear we shall not be able to see them in a completely darkened room, but that light of some kind must be present if we are to discern them at all. We realize, therefore, that colour is not a property of the object alone, but that it is dependent upon the presence of light. The reason that objects appear coloured is because they possess the property of absorbing some of the rays of light falling upon them while reflecting others. Transparent objects such as coloured glass and gelatine (the materials of which the colour filters are made which we shall use later) also possess this property of absorption, absorbing part of the light falling upon them and *transmitting* the remainder. Colour is the result of the absorption and the transmission, or reflection, of light.

As a simile, though perhaps not a very exact one, one may instance water running from a tap on to a sponge. Part of the water will be absorbed by the sponge, and part will splash off. In much the same way, part of the light is absorbed by objects and part is splashed off, or is reflected, and according to that part which is reflected, or in the case of a transparent medium, "transmitted", so we name the colour we see. Objects which transmit, or reflect, *all* the rays of the light which falls upon them we call white or colourless, and those which absorb the whole of the light falling upon them we term black, for black is an entire absence of light. When the object absorbs an *equal* part of *all* of the rays of which the incident light is composed, we speak of it as being a neutral grey.

The Spectrum

To return to the colours in the rainbow, or the spectrum, as it is more properly called, what is the reason for the appearance of these colours? Why is white light broken up into its component parts under such conditions? It is because the light on entering the raindrops, or the glass prism, is bent out of its original path. We are all familiar with the appearance of a walking-stick when it is poked into the transparent waters of a pool or stream—how the portion under the surface of the water appears to be bent slightly upwards; this is another instance of the bending of light, or refraction as it is called. If we take a rod made up of a number of splinters, say a cane rod that has been hammered until it has separated into its individual fibres, and if we bend such a rod, the fibres or splinters will spread out fanwise, showing the separate portions distinct and apart; so with light entering a medium such as the glass prism, or the spherical raindrop, the rod or ray of light bends and is split up into its component parts. In white light, such as sunlight, these components form a continuous band of colours ranging from deep violet at one end, through blue, blue-green, green, yellow-green, yellow, orange, to deep red at the other end. This is known as the visible spectrum. There are in white light, however, other wave-lengths, or portions of the spectrum, which are invisible to the human eye but to which the photographic plate is, or can be made, sensitive. They are the " infra-red ", which extends beyond the red end of the spectrum; and, at the other end beyond the violet, the " ultra-violet " rays. To these latter the emulsion of the photographic plate is especially sensitive, as will be learned later.

Seeing that the photographic plate, although it can be made sensitive to every colour in the spectrum, is not equally sensitive to them all, special arrangements have to be made to compensate for this. In the screen-plate processes, this is done by using what is known as a compensating filter over

the lens of the camera; in the subtractive processes, where three separate colour negatives are made, as required by the Clerk-Maxwell theory, the exposures of the negatives are varied to make up for this variation of sensitivity.

Sunlight has this continuous spectrum band, and is always composed of the colours indicated, but the proportionate amounts of these colours differ according to different lighting conditions. For instance, on a bright June day the band of violet and blue would be found to be of a greater strength than say towards evening in September, when the red and yellow bands would appear brighter. This, of course, is not due to an actual change of the light radiated from the sun, but rather to the atmosphere acting as a filter, which is a transparent medium absorbing some part of the rays—not necessarily completely absorbing any particular band of the spectrum (indeed if it did one could not at that moment successfully reproduce the colours of nature by any method based upon Clerk-Maxwell's theory), but rather absorbing a part of several bands.

Artificial Light in Photography

This variation in the composition of sunlight brings us to the question of the use of artificial light for colour photography. In answer to the query, can colour photographs be taken by artificial light, one can reply "Yes, provided the spectrum of that light *is* a continuous one." There is only one light likely to be met with in photography which is quite unsuitable for colour photography, namely, the mercury vapour lamp, though, curiously enough, this is very efficient for monochrome photography, and is used very largely for many branches of commercial photography. It owes its efficiency for monochrome photography to its richness in ultra-violet rays, to which, as has been stated, photographic material is exceptionally sensitive, but its uselessness for colour work is due to the almost complete absence of red rays in its composition. One can easily understand that if

there is no red in the light itself any object which we normally call red if seen in this light will not appear red, but in the complete absence of any of those red rays which alone the object has the power to reflect, it must and will appear black, since all the light that falls upon it is absorbed by it. This, of course, is the reason for the ghastly and death-like appearance of a ruddy-complexioned person seen in this light. The red lips, the pink of the cheek, absorb the light and appear black and grey respectively, while the whiter portions of the face reflect the colour of the light itself (white light minus red), a peculiar bluish green.

It will therefore be seen that, apart from a light such as that of the mercury vapour lamp, artificial light is quite suitable, though, as will be gathered from what is stated above, the spectral quality of the light has to be taken into consideration. Fortunately this involves no special knowledge or skill of any kind on the part of the worker, other than the ability to read and use the multiplying factors given for the particular light in use by the plate-makers themselves; but consideration of the above-mentioned differences in the composition of various light sources, and the inequality of sensitivity of the plate to different parts of the spectrum, should make it clear that it is not possible to use a mixture of lights of widely different spectral quality when taking colour photographs. In fact, under such circumstances, the object would be illuminated by light to which the plate used is variously sensitive, and the result would be a curious patch-work of colour totally unlike the appearance of the object to the eye. Do not, therefore, mix half-watt and arc-light (unless the arc is the so-called " flame arc ", which is very like the half-watt in spectral composition), nor artificial light and daylight, except when the composition of these is very nearly alike. We have perhaps gone somewhat far ahead, but the question of mixing lights is so often brought up that we feel it may quite properly be touched upon when dealing with the composition of light, since the *reason* for the answer given can then be understood.

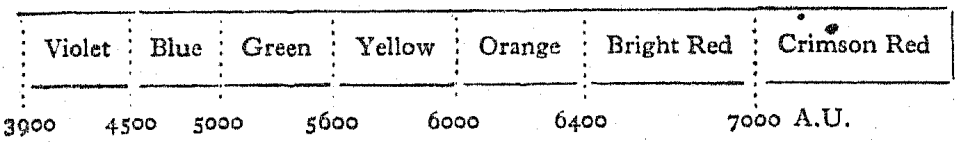
Physical Nature of Light

Before we proceed to the application of Clerk-Maxwell's theory to the practice of colour photography, we have still one or two theoretical points to consider.

The first point refers to the physical nature of light itself. The theory generally held to-day is that light is a form of energy which travels with a wave-like motion in the ether—that substance which is presumed to pervade all space and matter. Light waves may be likened to waves of sound, which vary in frequency of vibration. In sound, there are vibrations of high frequency, which our ears apprehend as high pitched or treble notes, and also vibrations of lower frequency, where fewer waves per second fall upon the ear, thus producing the bass notes of speech or music; so with light there are waves of varying frequency of vibration producing different results upon our optical receptive system. Some of these fall upon the eyes at a comparatively low frequency, others at double, or even a higher rate of vibration, and the colour of the light varies according to the rate of frequency of vibration.

The waves themselves are imagined to be similar in form to those caused when a stone is dropped into the still waters of a pond, which go travelling outwards in a series of crests and troughs—the wave-length being compared to the distance between crests of consecutive waves. The velocity of light is known; it travels through empty space or through air at the stupendous rate of nearly 200,000 miles per second. White light such as sunlight may be compared to sound in another respect also, since light consists (as we see in the spectrum) of waves of varying frequencies; and further, there are harmonies of colour as there are harmonies of sound. The distance from crest to crest of successive light waves is exceedingly short. These distances have been measured, the unit of measurement being known as an Ångström Unit (A.U.), which is a ten-millionth of a millimetre (a millimetre is roughly one-twenty-fifth of an inch).

The following diagram shows some of the wave-lengths in the spectrum together with the colours, as usually described, to which they correspond:



Colour and Vision

We may now consider how it comes to be possible to reproduce all the colours of nature with only three colours. To understand this, we must examine the theory generally held, and now fairly well substantiated, as to how the eye perceives colour. Many theories have been advanced from time to time purporting to explain the process by which the brain differentiates between various colours. The theory accepted at present, which was first enunciated by Thomas Young, is based on the hypothesis that we possess only three fundamental colour sensations. In our eyes there are supposed to be three kinds of nervous elements, which are stimulated by these three fundamental colours. One is stimulated most strongly by wave-lengths of light near 6000 A.U. in the orange-red portion of the spectrum; another by those in the yellow-green portion, and a wave-length of about 5600 A.U.; and the third by the blue region round about wave-lengths of 4650.

These nervous elements, or fibrils, may be likened to three wireless sets, one tuned or adjusted so that it would receive signals from the London broadcasting station at 261 metres, another from a station at 356 metres, and a third from the Midland region station at 479 metres; and just as these sets would only be stimulated by the wave-lengths to which they were tuned to respond, so, too, it is supposed the sensitive fibrils in the eye respond to the wave-lengths indicated. The simile may be stretched even further, for as the wireless sets will receive signals a little on either side of the specified wave-

band, though not so strongly as those for which they are specially tuned, so it is supposed the nerve fibrils are also excited in a lesser degree, but through a considerable range, by the wave-lengths of light on either side of the maxima.

One is obliged to emphasize that the existence of these fibrils is based solely upon the assumption that something of the kind must be imagined to exist, since no trace of any such nervous has yet been discovered by the physiologist.

When all three of these nervous elements are strongly and equally stimulated by light emanating from one source, the brain receives the impression of white; if equally, but more feebly, then the impression received is of grey; and according to the degree and intensity of the stimulation of one or more of the elements, so the impression of colour, of a corresponding degree of brilliance or intensity, is received by the brain. Thus, for example, if only the element sensitive to green is stimulated, the brain receives the impression of green; and other colours than the primaries are the result of the stimulation of more than one nerve fibril. It should be pointed out that if the patches of the primary colours are exceedingly minute, the eye is then unable to see them as separate units, and the whole area appears white. This is the property of vision upon which the mosaic screen-plate processes are based. It is analogous to " persistence of vision ", the well-known phenomenon which has made the cinematograph possible.

Experiment showing Blending of Primary Colours

In order to bring out more clearly how these theories fit into practice we will now describe an experiment which has been used to give an ocular demonstration of the results of blending lights of the three primary colours (see Plate, p. 12).

If either a triple lantern, or three lanterns, are so fixed that the beams issuing from them fall upon one and the same place on a whitened screen, it will be obvious that we shall have a circle of white light at that place. If, however, before

illuminating the screen in this way, we take one lantern only, and if in the path of the beam of light coming from it we place a piece of gelatine dyed with one of the primary colours, say the blue-violet, then the circular patch on the screen will be of that colour. If now we add a beam from a second lantern, and in its path interpose a filter, as it is termed, of red, then we shall see on the screen a mixture of red and blue-violet, which is generally called magenta. If finally we turn on the third lantern with a green filter in position, we shall find that all colour has disappeared from the screen, on which there will now appear a circle of white light similar to that seen at first, though perhaps, owing to the absorption of light by the filters, of somewhat lowered brilliance or intensity. The fact that we are able to produce white light by the admixture of the three primaries may be regarded as explaining why it is unnecessary to employ as many colours as can be seen in the spectrum, since if it is possible to produce the whole source of colour in this way it must be possible to reproduce any part of the whole.

The reason why we see this mixture of coloured lights as white is because the nerve fibrils have been equally stimulated, the eyes being focussed upon one patch of light.

If now the light from the blue-violet lantern is extinguished, the colour seen upon the screen will be a bright yellow, because in this case only the fibrils stimulated by red and green are excited, and when this is the case the brain receives the impression of yellow.

It should be borne in mind that at the moment we are dealing with the effect of the admixture of coloured *lights* and not pigments.

The diagram opposite p. 14 deals with the admixture of coloured lights, which in photography is known as the additive method. The diagram has been modified somewhat in form, the circles of light from the three lanterns being made to overlap for the sake of clarity and in order to explain the meaning and formation of the complementary colours.

Filters

The three primary colours are used in the form of filters to analyse the colours of the object photographed. Filters are used in many forms, but in any case they are employed somehow or other in front of the panchromatic emulsion of the plate or plates so that the light reflected from the object has to pass through them before it can act upon the plate itself.

It must be borne in mind that we never encounter in nature any colours which are absolutely pure spectral colours. The greens, reds, or blues are never exactly the same colour as our green, red, or blue primary colours, but are always mixtures of these. We therefore use our primary colours in such a manner that they act as filters, and filter out as it were (or more correctly absorb) any colour that we do not want to act upon the plate. Thus filters are used as a means of producing photographic records of the amount of blue-violet, green, or red contained in the colours of the object. The filters may consist of thin sheets of gelatine dyed the primary colours, or they may be tiny irregular dots of gum or resin or of starch grains, or they may consist of regular squares or lines printed on glass or film; but no matter what form they take their purpose is the same, namely, to analyse the colours of the subject photographed and to form a photographic record of their amounts. In the screen-plate processes they are used in the dot form, either actually on the same plate as the emulsion, or on another in close contact with it.

The Additive Process

In order to make it clear how the colours are formed in the additive process we shall suppose that we are given a circle of pure red against a white background.

A negative is taken of this through the blue-violet filter and would appear as diagram A, i.e. a black outer square with a circle of clear glass in the centre corresponding with the circle of red. In this case the filter passes the blue-violet

reflected by the white background and gives a black image on the plate. It absorbs the red rays reflected from the card and therefore no action takes place upon the plate in that area. If this negative were put into a lantern and projected through a blue-violet filter we should have a black outer square and a blue-violet circle—the opposite of what is required. A positive A_1 has therefore to be made from the negative A.

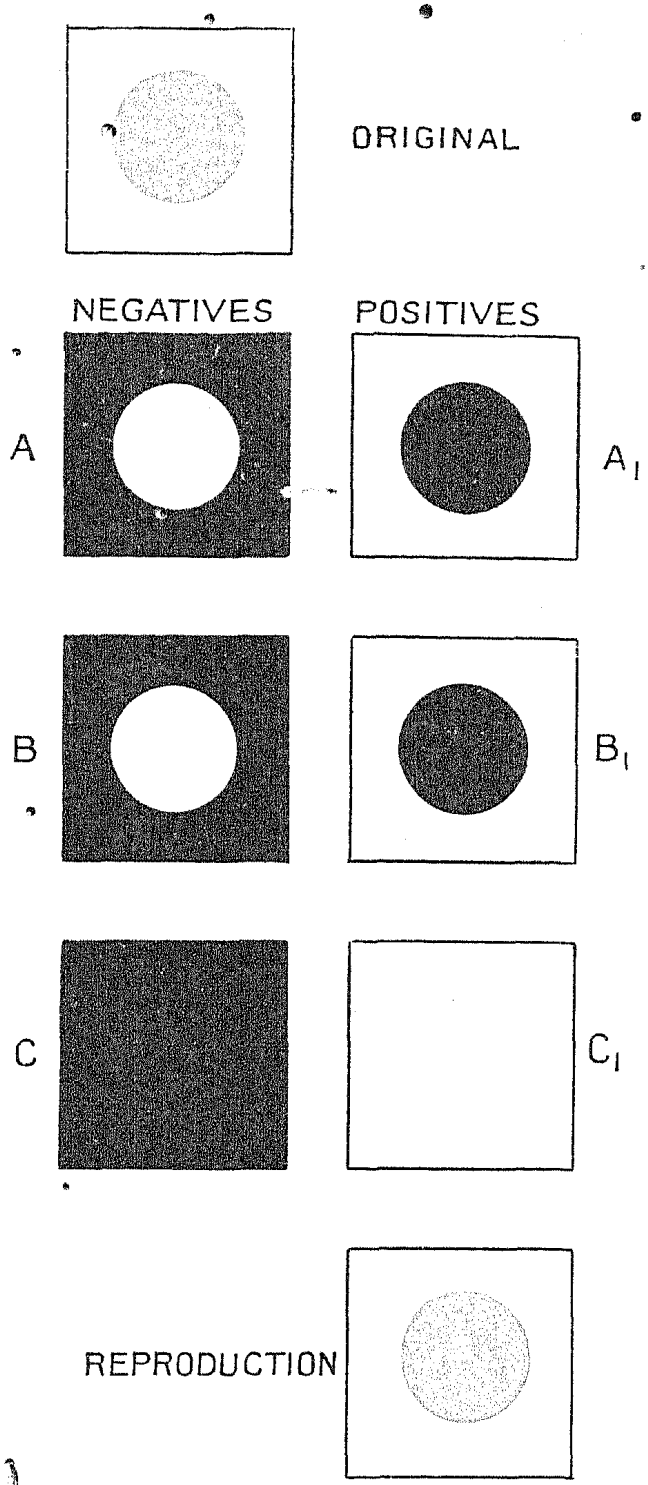
A second negative is taken through the green filter and would appear as diagram B, for precisely similar reasons as in the case of A. A positive B_1 is therefore made from B.

A third negative is taken through the red filter and would appear black all over, as in C, since the red light reflected from the card would also act upon the plate. If this were put into the lantern no light could pass at all. A positive C_1 is therefore made from the negative C.

If these positives are put into the lanterns, and the images are projected through the original filters on to the screen, we should get the correct reproduction of the original for the following reasons. A_1 would let blue-violet fall upon the screen on the outer square, but the circle being opaque would not transmit any light; B_1 would transmit green light to the outer square and none to the circle; C_1 would transmit red light to the outer square, and red to the circle also.

In describing how this explanation applies to the screen-plate processes (these get their name from the fact that filters are sometimes known as "screens"), we will take the case of a screen-plate (the Finlay) in which the screen is composed of tiny squares of red, blue-violet, and green in regular pattern too small to be seen with the naked eye. These squares are printed on a separate glass plate, sometimes called a mosaic screen, and this is put in close contact with the negative plate itself in the dark slide, the photograph being taken through these "filter" squares.

The negative taken through these, although to the eye like any ordinary negative, is actually made up of tiny squares of black, grey, and clear glass. The three negatives in dia-



HOW THE COLOURS ARE FORMED
IN THE ADDITIVE PROCESS

Facing p. 14

grams A, B, and C are actually combined in this single negative which has been taken through this mosaic screen.

If this negative is put into register with the mosaic screen through which it was taken and held to the light, or put in a lantern, the outer square would appear black because all the colour squares of the screen would be covered by the corresponding squares of the negative, and would permit no light to pass through them. In the circle all the red dots would be covered (because in making the negative the light went through them); all the green and blue-violet squares would be clear glass since no light was transmitted. On our screen we should have the outer square in black and the circle blue-green.

A positive has therefore to be made from the negative, and when this is in register with the mosaic screen the effect is reversed. Light can now pass through all the minute squares on the outer portion of the film; this causes all three of our nerve fibrils to be excited equally (the dots are too small to be seen separately), and we see white upon the screen. In the circle the blue-violet and green squares are covered, and light passes through the red ones only, thus giving a correct reproduction of the original.

Subtractive Processes

We have next to consider the subtractive processes, in which the colours are produced in rather a different manner. As examples of the subtractive processes we have colour prints on paper, as well as all the various mechanical methods of three-colour photography, half-tone, colour gravure, and the like. Here the colours in the result are produced by using, not the colours of the filters through which the negatives are made, as in the screen-plate processes, but the colours that are complementary to them. By complementary in this instance we mean the other colours which, together with the one in question, form white light. For instance, in the experiment with the lanterns, it will be remembered that when we shut

off the blue-violet light we saw yellow upon the screen; we therefore speak of yellow as being complementary to blue-violet, and make the print from blue filter negatives in yellow.

When the red light was cut off we had a mixture of blue and green on the screen; blue-green being the complement of red, the print from the red filter negative is made in a greenish-blue.

The mixture of blue and red make, as has been stated earlier, magenta, which is the complementary colour to green, therefore our print from the green filter negative is printed in magenta.

That we *must* print in the complementary colours will be seen clearly when we come to consider the effect of making the negatives through the tricolour filters.

Filters and their Uses

We see then that filters may be described as the means employed to analyse the colours of the object photographed into their three components, in order that we may make negatives recording the respective amounts of each colour in the object. It is not necessary in a book of this nature to do more than explain in a general way what functions the filters perform; those who wish for further information should read Dr. Kenneth Mee's book, *The Photography of Coloured Objects*.

Obviously before the tricolour filters can be used in the way just described we must have plates which are sensitive to the colours which they transmit; we must therefore work with panchromatic plates, which are sensitive to all the colours of the spectrum.

The filters most generally employed nowadays are of two types. Those of the first type are made of sheet gelatine, dyed the appropriate colours, and are used as a rule by those who are making their first acquaintance with trichrome photography, and wish to find out its possibilities before indulging in the more expensive forms. Those of the second

type are for more serious work, and are made with thin gelatine film cemented between two pieces of optically worked flat glass.

If filters of the second type are to be used on the lens, it is essential that the glass should be optically worked flats, or the optical qualities of the lens will in all probability be disturbed. If, however, they are to be employed immediately in front of the plates, then a good quality white glass free from blemishes will answer the purpose. If used in film form they may be used either in front of, or behind the lens, as the thinness of the film does not seriously affect the optical system, but great care must be taken in handling them in that form as they are easily damaged.

Example Illustrating the Action of Filters

To illustrate the action of the filters by an actual example, we will imagine a photograph taken of a colour print of a pure red tulip, with green foliage, in a blue jar on a black table, as in the diagram opposite p. 18. It should be understood that in the diagram no attempt has been made to deal with any other than flat solid colours; half-tones and light and shade have been disregarded, except in the grey background, which has been inserted to emphasize the fact that a neutral grey such as this will be rendered alike in each negative and positive. Further, the explanation is not intended to be strictly scientific, but rather to give a broad idea of the formation of the colours. For instance, no account is taken of the fact that filters neither transmit nor absorb the light in the proportions that theory demands, and no consideration is given to the shortcomings of the pigments employed, in regard to their absorption and reflection of light. To include these matters would only tend to confuse the mind of the reader. Those desirous of more exact information should consult the work *Panchromatism*, by Messrs. Ilford, Ltd., or Dr. Mee's book mentioned above (p. 16).

Fig. 1 represents the colour print; A the blue-violet filter

in front of the lens of the camera; B the negative after development. Note that the blue-violet filter transmits the blue light reflected from the jar, and the negative shows a black deposit of silver corresponding with the jar. No light is reflected from the table, and the filter absorbs the red light from the tulip and the green from the foliage, so that only the merest trace of these is seen on the plate; this mere trace (supposing the colours pure and the filters theoretically perfect) is due to the surface reflection of the incident white light. The grey background reflects a certain amount of white light which is, of course, transmitted by the filter and records as a half-tone on the negative. Now in the subtractive processes the negative itself is not converted into a colour image but a positive from it is used to provide this; C is the positive, in which the effect, as one would expect, is reversed. Here we have a blank space corresponding with the jar, while the flower, the foliage, and table form a heavy black image. This is the case whether the printing in colour is to be done by mechanical means, and the positive is in the form of a block composed of squares and dots made by the half-tone screen, or whether the colour positive from it is made photographically as a dye or pigment image.

If we consider a moment we shall realize that it will be useless to print from this positive in the same colour as the filter; if we did so we should at the start have a blue-violet blossom; therefore, since the positive is the opposite of the negative we must print in the opposite, or more correctly, the complementary colour of the filter, in this instance yellow.

In fig. 2 we see the result of using the green filter E. F is the developed image on the negative, and since the filter transmits the green light from the foliage we have a black image of that, and a half-tone corresponding with the grey background, as in fig. 1, the remainder being white or clear glass, as the colours of these are absorbed by the filter. G shows the positive with these effects reversed, and H the colour positive in magenta, the colour complementary to the filter.

Fig. 3 shows the effect given by the red filter. In J, since only the red of the flower is passed in full, we only have that portion in full strength black, the remainder being as explained in fig. 2; K, the black-and-white positive; L, the image in blue-green, complementary to red of the filter.

We have now to consider the effect of combining the three images. Imagine the blue-green image to be superimposed over the yellow. The blue-green of the foliage will combine with the yellow to give the correct colour of green. The blue-green jar will fit into the blank space of the yellow positive, while the yellow blossom will fit into the blank space in the blue image.

The question will naturally arise, why print yellow in the flower space? The reason of course is that we are going to superimpose there, not a pure red, but a magenta (a bluish-red), and the yellow is necessary in order to absorb the bluish part of that image from the light reflected back through it from the paper support, in order to give the pure red required.

So, too, with the half-tone of magenta in the jar. This is required to absorb the green that is present in the blue-green image, and so give the neutral blue of the original painting.

The full-strength portion of each colour positive in the table absorbs all the light falling upon it and gives the desired black, while the half-strength of the background in each, being of equal light-absorbing power, gives the neutral grey of the original.

It must be obvious, of course, that the foregoing explanations would only be absolutely accurate if the dyes in the filters and the colours of the printed images were theoretically correct in their absorption and transmission of light, and if also negatives and positives were of correct gradation. Unfortunately none of the dyes and pigments available conform exactly to these requirements, but improvements introduced in recent years have made it possible to obtain a very close approximation to truth in colour reproduction.

Those interested in fuller information on these matters should consult Wall's *History of Three-Colour Photography*, and Dr. Mee's *Photography of Coloured Objects*.

CHAPTER II

Exposure

Importance of Accurate Exposure

The exposure problem is the most important one confronting the colour photographer. Upon the correct determination of the exposure hangs the quality of the final result. More especially does this apply to the screen-plate processes of the combined type—the Autochrome and Agfa colour plates—for with these over-exposure can be as disastrous as under; and although with the other method of colour photography the great latitude of the modern dry plate can be taken advantage of, and errors if made in the direction of over-exposure are not specially serious, yet there can be no question that the finest technical results are to be obtained from plates to which the most nearly accurate exposure has been given. The worker is therefore strongly advised to pay particular attention to the exposures of his plates.

It has to be remembered that not only has the quality of the light to be considered, but the nature of the subject—whether it is dark or light, near or far away from the camera—indeed, the correct classification of the subject is of equal importance with the actual value of the light.

When dealing with a subject consisting of masses varying very much in their relative darkness, the worker must make up his mind as to which portion of the scene is most important, and the exposure should then be based upon the time required to give the necessary detail in that particular part.

Light Measuring Meters

When the light is being measured by one or other of the light measuring meters, as opposed to the calculators, it is often a good plan to measure the intensity of the light in the lightest portion, say, for instance, the sky when it is desired to retain some beautiful cloud formation, and then to measure that in the darkest portion in which detail is required, and to give an exposure which is a compromise between the two. This advice applies more to the transparency worker than to the maker of colour prints; to the latter the advice to expose for shadow detail applies as in ordinary photography.

Calculators

The system embodied in the calculator method of arriving at exposure largely depends for its success upon classification of the subject under the headings given by the makers of the instrument. This is not always an easy matter to decide upon; one so often comes across a subject, especially in landscape work, which does not seem to fit under any of the headings given. The thing to do is to endeavour to arrange the amount of light and shade in the masses, and the distance from the camera, in the mind's eye, and to mentally appraise it so that one can say, " Well, it isn't so and so, or so and so, but I imagine it presents about the same amount of shadow and high-light as so and so."

In the Burroughs and Welcome Calculator and Diary there is an excellent series of photographs illustrating the various classifications of subject, which are a great help in arriving at a correct decision.

Choice of Meter

As to the best type of meter to use, this is largely a matter of personal taste, and it is difficult to express an opinion as to which is the most suitable. The writer has used most

kinds with success. The important thing is to try the type which, for one reason or another, appeals to one, and then to stick to it until its peculiarities are thoroughly mastered, when it will be found that one can get satisfactory results with almost any type. Personally, the writer has of late found the extinction type of meter, of which the Justophot is an excellent example, of very great value, more particularly because of the wide range of subjects embraced by it, since objects illuminated by artificial light can be dealt with as easily as those lighted by daylight. Some workers view the extinction meter with disfavour because the personal factor of one's eyesight enters so much into the conclusions as to the exposure arrived at by its aid; but here again it is a question of getting used to the particular type, and making the necessary allowances for one's own eyesight. That is to say, if the exposures give negatives that are under-exposed, compensate for this by taking the reading of the figure at a greater brightness than before. Conversely, if it produces over-exposed negatives, let the figure fade out more before taking the reading.

Certainly the Justophot has in the author's hands been invaluable in arriving at the correct exposure in cases where previous experience was of no assistance, and in which it would have been impossible to get a tint with a tint type of meter, as for instance in photographing illuminated transparencies, and in many cases where artificial light was the illuminant. Then, too, the exposure calculator, such as the one to be found at the back of the Burroughs and Welcome Photographic Diary, is most useful, and for many years was the sole means used for arriving at the correct exposure; that too proved invaluable.

On the other hand, other workers declare that only those meters which actually measure the actinic value of the light can be depended upon. Thus, for example, the makers of the Watkins Bee meter issue a special dial for use with the screen-plate processes. They maintain that the usual laws, regarding the increase of exposure necessitated by diminishing

the aperture of the lens, do not apply to the screen-plate processes. They have accordingly worked out a special dial for these plates, and this should be inserted in the instrument instead of the standard dial issued for monochrome work.

The whole question is an instance of the old adage, " When doctors disagree the patient may take his choice ". The great thing is, as has been said, to choose the instrument which most appeals, to thoroughly master the instructions for using it, and then to apply one's intelligence; then almost any type is good, and some are excellent.

Exposure for Shadow Detail

With reference to negatives for colour work on paper, the advice given for monochrome photography of exposing for shadow detail holds good. It *is* possible to deal with a plate upon which some light action has taken place, but it is obviously impossible to improve, by any amount of intensification, detail which is not upon the plate at all; therefore under-exposure is always to be avoided.

Small Stops and Brilliancy

Some workers have stated that it is impossible to get brilliant colours if small stops are used, whether in transparency or in colour prints. This has not been the experience of the writer, who finds it difficult to imagine any possible reason for such a result, provided a *sufficient* increase of exposure is given. This should, in these cases, be considerably in excess of the exposure given for equally small stops when used for monochrome work. Not less than double the indicated exposure should be given if stops smaller than F. 32 are used, since the inertia of the emulsion has to be overcome before the light action begins to take effect. The filters probably exert a damping effect here, which has to be taken into account. Provided, however, this is done, there should be no difficulty in obtaining brilliant colours in the result when small stops are used.

Advantages of Small Stops with Long Exposures

The use of a very small stop, say F. 44, and a long exposure, which may run into anything from 10 minutes to half an hour, according to lighting conditions, provides an excellent way of dealing with the difficulty of persons moving across the field of view. As an instance of this, the writer exposed an Agfa plate for 12 minutes at F. 44, when taking a view of the Kursaal at Interlaken, and except for a couple of inquisitive people who stood watching for 5 minutes to see when the fool of a photographer was going to start taking the picture, no sign at all is to be seen of the throngs of people passing to and fro continuously in front of the camera. Of the inquisitive ones there is but a ghost, the reason of course being, that since 12 minutes' exposure was necessary to produce a properly exposed plate, obviously those who were only in front of it for a minute or so, would not be there long enough to make any impression. Further, such exposures help to get over the difficulty of occasional movement of flowers, &c. Many a time has the author taken advantage of this, to get both a picture and a rest, when photographing in Kew Gardens in the evening. On these occasions he has frequently given exposures running to half an hour, and thereby secured pictures which were both colourful and brilliant.

That the argument against small stops is a fallacy may be considered to be proved from the fact that the process worker almost invariably works with a very small stop, and a proportionately long exposure.

CHAPTER III

The Subtractive Processes

MAKING THE NEGATIVES

The general principles underlying the subtractive process in colour photography have been explained at p. 15, where also an example was given to illustrate the action of filters. We have now to consider the method in detail.

Although it is possible to produce the three-colour separation negatives by a single exposure, either in a one-exposure tricolour camera, or by means of a film tri-pack (three films in intimate contact one behind the other, with the necessary means of colour separation incorporated), neither method is at present readily available. The cameras in question are extremely costly, owing to the delicate adjustments necessary to overcome the inherent difficulties of obtaining three identical images simultaneously; and for many reasons they cannot be regarded as being altogether satisfactory in use.

One form of tri-pack recently made available to the public has been withdrawn from the market, while another, which from the theoretical standpoint was the more desirable, is at the moment being produced for factory use and is not readily obtainable by the amateur photographer. This tri-pack gives extremely good colour separation, and follows correct theoretical procedure in its form; but it produces rather soft diffused results, which though excellent for portraiture (for which purpose it is manufactured) does not lend itself to subjects where critical definition is desired.

Those, therefore, who wish to attempt colour photography on paper must be content to make their colour separation negatives one after another. If this be done by means of separate plates (or films), thus necessitating the changing of the filter as well as of the plate or film for each exposure, the

field of work is somewhat limited. The time required to make the changes puts any work where movement is likely to take place, as in portraiture, out of the question; but for still-life subjects, copying paintings, or similar work, the exposures can be made in this manner.

The first essential is a camera upon a good firm stand, one which will not be shaken or moved during or between the exposures, as for instance when the dark slides or filters are being changed. Rigidity is essential, for any movement will prevent the subsequent registration of the three positives. A very useful bracing strut has recently been put upon the market by Ensign Ltd.; this effectually prevents movement of the tripod even on the most slippery surfaces. It costs only three shillings, and can be regarded as almost indispensable by the colour photographer.

For first attempts the gelatine type of filter is quite suitable if it is used with care. Gelatine filters may be procured at a trifling cost from the makers of the panchromatic plates or films which it is intended to use. It is advisable to use filter and plate of one make and to avoid "ringing the changes" upon them, since the possibility of error is introduced by so doing. If filters in this form are to be used on the lens (as is best), some kind of holder is necessary, since they are easily damaged by moisture from the fingers when handling them.

One method is to use three pill boxes which will slip on to the lens mount; the bottoms are taken out of these, and the gelatine films carefully stuck on in their place.

Perhaps the best way is to mount the filters side by side between two pieces of card, with square or circular apertures cut in them, as shown at A, fig. 1. The combination slides through the holder B, which is slipped on to the lens mount. Holders of this type can be made of tin, or thin brass, or even cardboard, by the handy man; or those on the market for use with ordinary filters will answer admirably, provided the card can be slipped through.

Method of Making Cardboard Filter Holder

In making this holder, the two sides should be cut from fairly stiff card, and the apertures cut in them large enough to permit the full aperture of the lens to be used. They should be stuck together with a piece of lantern-slide binding tape, as shown in sketch.

The squares of gelatine film, which should not be handled with the fingers, but lifted from the paper wrapping with

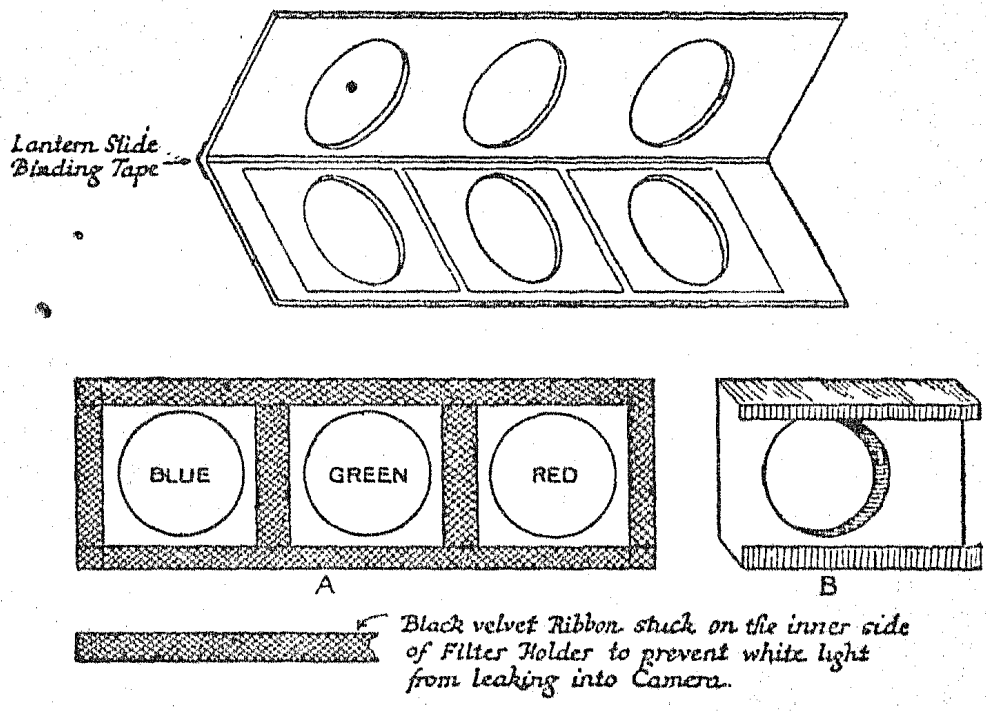


Fig. 1.—Filter Holder

tweezers or a small pair of scissors, should be laid over the apertures on the lower card, and held in position with a smear of seccotine. They should be mounted in the order shown, i.e. alphabetically, as one is then unlikely to get muddled; and the two cards should be folded together and bound round the edges with binding tape.

The cards should be blackened, and if they fit loosely in the outer holder, black velvet ribbon, as shown, should be

stuck round them. White marks should be painted on the back of the card, so that it may be possible to see when each filter is centred in front of the lens, without coming to the front of the camera.

The Kind of Plate to Use

The plates or films used, as has already been mentioned, *must* be panchromatic. If plates are chosen, it is almost equally essential that they should be backed, halation being fatal to success in colour photography. They can be obtained ready backed at a very little higher cost.

Although these plates *may* be used with a green safe-light, it is not at all difficult to load and unload the dark slide in total darkness, and it is certainly preferable to do so. One can practise with old plates beforehand, and with very little experience the difficulties will disappear. Panchromatic plates are packed in pairs face to face, and the backing can usually be detected by the sense of touch, as it is slightly less smooth than the emulsion.

Loading the Dark Slides

When loading the dark slides it is advisable to avoid, if possible, taking the plates to complete a set of three from different boxes, unless the batch number is the same, since although every care is exercised by the makers to keep the emulsions of various batches constant as regards speed and colour sensitiveness, these may vary slightly. If one is at the end of a box, it is better to leave an odd plate or two, to be used for monochrome work, and take the three for the tri-colour exposure from a fresh box, rather than run the risk of the two boxes varying to any considerable extent in either of the qualities mentioned, and so upsetting the balance of the set of negatives. When one is buying several boxes at a time it is best to ask for them all of one batch; and as every batch is numbered on the box, it is easy to see whether the plates from two boxes can be used together.

Choice of Subject for Exposure

As a subject for the first exposure nothing is better than still life or a simple flower study. A wedge should be placed close to the objects in such a way that it is photographed and appears on the negative, but can be trimmed off the prints without spoiling the picture. A wedge, by the way, may consist of a strip of bromide paper printed in a series of steps ranging from black at one end through greys of diminishing strength to white at the other. Ready-made strips can be got from the Autotype Company. The reason for using the wedge will be explained later.

After the subject has been arranged and focussed, everything must be screwed up tightly so that there is no fear of movement either of stand or camera. The exposure should be determined by means of an exposure meter or calculator (see chapter on Exposure, p. 20).

Although the modern panchromatic plate possesses quite enormous latitude, it is obviously desirable to have the negatives correctly exposed, for much time can be wasted upon those which are not so, the proper place for which is the dustbin. The correct exposure having been determined, it is multiplied by the filter factors for the respective filters; these factors are given in a leaflet enclosed in the box of plates or films.

Filter Factors and Exposure

The factor numbers given by the manufacturers vary according to the make of plate and the actual batch of emulsion, but with the standard filters in general use they will be found to be about 4–5 for the blue, 10–12 for the green, and 7–8 for the red. (The figures given apply to daylight; artificial light factors differ considerably from these, and are to be obtained on request from the manufacturers.) This means that if the normal or unit exposure already calculated is one second, then the plate exposed through the blue filter must receive

4–5 seconds, the green filter plate 10–12 seconds, and the red 7–8 seconds.

In making the exposures, the three plates are exposed in turn, care being taken to change the filter as well as the plate, and to give each plate its correct exposure according to its filter. Forgetfulness of any of these points can only be remedied by making a fresh exposure on another plate. Care must be taken when withdrawing the shutter of the dark slides not to move the camera; if these work stiffly they should be made to slide freely by rubbing the edges with a little black lead.

Developing the Plates

When the exposures have been made, the next operation is development. Here again one is restricted to working either in complete darkness, or in the dim light of a green safe-light, unless a desensitizer is used. This latter procedure is strongly recommended, and there are several excellent desensitizers on the market. They may be used as an addition to the developer, but the better way is to have a separate dish considerably larger than the plate to be used, and to put a fairly liberal amount of desensitizer in it. A second dish with the developer recommended by the plate-maker should be placed near the first. It is advisable to use the formulæ given by the makers as they also give time and temperature tables to be used in conjunction with the formulæ. These should be referred to, and the time which they give, corresponding to the temperature at which development is to be carried out, should be noted.

Development should not be carried too far, as excessive contrast should be avoided.

If the worker has a marked preference for any particular developer, it may be employed, for any well-balanced developer is suitable; but the time and temperature method of development is preferable to any method of inspection, so that unless these particulars are available, it is better to use the maker's formulæ. It should be borne in mind that each

negative must be developed in a fresh portion of developer for exactly the same time.

A third dish with an acid-fixing bath is placed in readiness.

Desensitizing the Plates

The dark-room light is turned out, the first plate is removed from the dark slide and slid face upwards into the desensitizer in total darkness, and the dish is rocked in both directions and covered with a card. The dark-room light (a bright orange light may be used) may now be turned on and the time noted.

At the expiration of the time given for the desensitizer in use (one or two minutes) the plate is taken out and slipped into the dish containing the developer. This dish should also be covered with the card, as it is inadvisable to expose the plate unnecessarily to the light even when using a desensitizer. The dish should be rocked in both directions to avoid markings on the plate, for the time given on the development card. The plate is then given a brief rinse in water and put into the fixing bath. Fixation should be complete in about twice the time taken for white emulsion to disappear.

The backing on the plate can be ignored until the washing of the plate is completed, when it should be removed with a tuft of cotton wool before setting the plate aside to dry. It is advisable to gently swab the emulsion side of the plate with cotton wool under the running tap in order to get a perfectly clean surface.

The desensitizer should be filtered occasionally to remove any particles of emulsion or other foreign matter.

Other Methods of Making the Negatives

Before going into the various methods which can be employed for the production of the prints, we may mention certain devices which may be used for simplifying the taking of the negatives so that the field of work may be increased.

One piece of apparatus recently introduced by Captain Owen Wheeler, F.R.P.S., known as *The Ross Rotator*, has

the filters incorporated in a circular metal disc which rotates between the components of the lens. The filter apertures differ in size and have been graduated to suit the filter factors, so that the exposures to be given are now the same for the three negatives. This is obviously an advantage, as is also the small bulk occupied by the Rotator, but it should be pointed out that the Rotator has to be used with a special lens and mount specifically adapted to it.

The Repeating Back

Another piece of apparatus which is very popular with three-colour workers is the Repeating Back. This is a piece of apparatus designed to fit upon the back of any camera which can be fitted to a stand, from one taking a $3\frac{1}{2}$ by $2\frac{1}{2}$ in. plate up to whole-plate size or larger. It consists of three parts. The first part is a long frame, having a central rectangular opening corresponding in size with the negative required; attached to this frame is a fitting identical in size with the ordinary focussing-screen holder of the camera, for which it is substituted. The second part is a focussing-screen, which slides in grooves at the top and bottom of the long frame, and is used for focussing in place of the screen belonging to the camera. The third portion, which is made to slide in the same grooves, is fitted with three-colour filters fixed side by side. It carries behind these the dark slide, containing a long narrow plate on which the three exposures are made side by side. On the lower edge of the Back a spring catch is fitted, which goes into slots in a brass strip on the sliding portion, and which ensures accurate centring of the plate and filters, behind the rectangular opening in the Back itself.

To use this piece of apparatus the ordinary focussing-screen is removed, and the Back with the small focussing-screen in position is put into its place. If the picture is to be a horizontal one (i.e. with the longest side horizontal) the Back is used vertically—if the picture is a vertical one the Back is used horizontally.

The picture is focussed in the usual manner, the focussing-screen removed and the sliding portion containing the dark slide inserted in the grooves. The lens shutter is then closed, and the sheath of the dark slide withdrawn. The Back is now ready to make the first exposure. This being given, the catch is depressed and the sliding portion moved along until the catch engages in the next slot on the holder. The second exposure is then given, and the operation is repeated for the third. The sheath of the dark slide must be replaced before removing the dark slide from the holder, otherwise, of course, the plate will be fogged.

It will be appreciated how much more rapidly the three exposures can be made with this piece of apparatus than with separate plates, filters, and dark slides, or even than with roll films or film packs, since these also entail a separate operation to change them.

Tricolour Compensating Filter

With the introduction of the Autotype compensating filter it has been possible to add still further to the usefulness of the Repeating Back, for this enables equal exposures to be given to each negative, irrespective of the colour of the filter through which it is made.

The compensating filter is in two forms, one for use with daylight, and one for half-watt electric light. The filter is, of course, used in *addition* to the tricolour filters, *not* in place of them. It is fitted in one of the usual filter-holders either in front of, or behind, the lens. If used in front of the lens it is immaterial whether it is in position when the focussing is done or not, but if used behind the lens it must be in position when the picture is being focussed. This is necessary because the filter in the rear position throws back the focus slightly owing to the bending of the rays of light passing through it.

If the compensating filter is employed, then the ordinary tricolour filter factors can be ignored, the normal unit exposure being now multiplied by 20 for each exposure whether

for the daylight or for the half-watt filter. This not only means that troublesome calculations in working out the three exposures are avoided, but also that extremely short exposures can be dealt with satisfactorily. When the normal exposure is very short, 1/200 of a second, for instance, it is obviously almost impossible to use the normal tricolour factors with this, and the only thing to do under such circumstances is to stop down the lens until the figures become manageable. With the compensating filter, however, the figure is multiplied by 20, so that 1/10 of a second is given to each exposure. Such figures make many subjects possible which otherwise are very difficult to take, and portraiture becomes practicable.

The Repeating Back can really be regarded as a *sine qua non* to all who intend taking up three-colour photography at all seriously, for besides possessing the advantages enumerated above, it is more economical in many ways—it needs only one plate instead of three, and it does away with the costly optically flat filters which are almost essential if permanent filters for use on the lens are required. Further, it simplifies the operations of developing, fixing, and the making of enlarged prints, while its use eliminates the snag which may arise from variations in the emulsions of different boxes of plates. Indeed, if three-colour photography were deprived of the aid of such a fitting, and had to depend solely on the orthodox method of plate and filter changing, it is to be feared that its scope would become so limited, and the number of operations so many and varied, that any but the most enthusiastic amateur would have his enthusiasm damped and his interest stifled at the start. The initial cost of the Repeating Back, not in itself a great one, is well repaid in every way.

So much for the preparation of the three-colour separation negatives.

PRINTING METHODS

The Jos-Pe Process

We now come to the choice of printing methods. Many methods have been evolved in the past, but those commercially available at the moment of writing are: Trichrome Carbro, Dyebro, Jos-Pe.

The Jos-Pe is a most interesting process, and perhaps in some respects simpler to work than any other, but it is not at the moment available to the amateur in this country, owing to the rights of use having become involved in legal difficulties. Like other dye processes it is not in great favour with amateur workers, inasmuch as the dyes have a way of staining the fingers and getting splashed on the table, floor, and walls. While this might not affect the enthusiastic worker, it would in all probability result in unkindly criticism from his feminine relatives. Quite frankly, in the interest of family peace, unless there is a room to be devoted entirely to the purpose, the dye processes are not to be recommended. They possess certain advantages over pigment processes, but in the author's opinion they never quite reach the same high standard of quality as the best of the pigment processes can give.

The essence of the Jos-Pe process is that glass plates or celluloid films are coated with a light sensitive emulsion, which is prepared with a very soluble type of gelatine, and contains only a small proportion of silver. If contact prints are required from the tricolour negatives, the film is used; if enlargements are to be made the glass plates are employed; the essential thing is that they *must* be printed *through* the glass or celluloid, so that the *back* of the emulsion is affected by the light.

After exposure they are developed in a special developer (probably pyrocatechin) which tans (i.e. hardens and makes insoluble) the gelatine of the emulsion wherever the silver image develops.

When development has been carried on for a sufficient

time, the plate is immersed in a stop bath of potassium meta-bisulphite, and then without fixation is immersed in warm water. The gelatine which has not been acted upon is still soluble and dissolves away, and after rinsing in hot running water, an image in gelatine relief is left upon the plate. The other two negatives are printed from similarly, and the three positives are dried. They are then immersed in their respective dye baths, until fully swollen again.

In the meantime a piece of transfer paper has been soaked in cold water. The blue-print plate, as it is called, is then rinsed under cold water and applied to the transfer paper, the latter being squeegeed into intimate contact with the former. After about five minutes, the paper is peeled off and, owing to the transference of the dye, will be found to have on it a replica of the image from the plate.

The yellow plate is then washed and applied to the paper bearing the blue image, the two are quickly registered, and the transference of the yellow image takes place. The operation is repeated with the red print plate, and the finished print in colour is the result.

This brief outline has been given in case in the near future the process may again become available to the general public. With regard to the other processes mentioned, inasmuch as Trichrome Carbro employs means with which most photographers have some acquaintance, and as it also is the base upon which the Dyebro process is built, it will be advisable to begin with this method. Further, as a matter of actual fact, Carbro can produce results which are unexcelled by any other process.

TRICHROME CARBRO

Three-colour Carbro, or Trichrome Carbro, as it is usually called, is, like its monochrome namesake, based upon the production of a pigmented gelatine image from a black-and-white bromide print. It is an extremely fascinating process

to work, and after the bromide prints have been prepared—these by the way may be used several times—the whole process can be carried out in daylight. The formation of the image is not due to the action of light, but to a chemical reaction which takes place between the silver image of the bromide print (i.e. the black and grey parts of the picture) and the soluble gelatine coating of the Carbro tissue in which the pigment is incorporated.

The Carbro tissue, which is sensitized at the moment of use, is brought into contact with the bromide print, and the silver image immediately commences to render the gelatine of the tissue insoluble. It does this in exact proportion to its own depth of deposit, so that where there is a very black portion in the picture, a very strong degree of insolubility is produced; where there is less silver, as in the grey portions, correspondingly less strong action takes place; and in the white parts, no action occurs in the tissue.

The Carbro tissue is then removed from the bromide print, squeegeed upon a support, and later put into hot water. The gelatine which has not been made insoluble (insolubilized) dissolves, the paper backing is stripped off and thrown away, and gradually there appears upon the support an exact reproduction of the bromide print, but in the colour chosen instead of in the black-and-white of the original print. When wet the image can be seen in high relief, the dense shadows being thick and swollen, the half-tones less thick, and the white high-lights quite clear and free from deposit.

This description refers to the reproduction of a bromide print in monochrome, but it applies equally to three-colour reproduction, except that in that case, instead of one bromide print, three are used, one from each of the colour separation negatives. The colours used, as explained earlier (p. 15) are complementary to the filters through which the negatives are taken, i.e. the bromide print from the blue-violet negative is reproduced in yellow, the one from the green in magenta, that from the red in blue-green Carbro tissue (see Plates, p. 40).

Before going into the actual details of the reproduction of these Carbro positives, it will be advisable to emphasize the necessity of making the best bromide prints the negatives are capable of yielding. From the outline given of the process it is easy to appreciate how very important a part the bromide print plays. The slightest veiling of a high-light, whether it is wanted or not, will produce a corresponding deposit of colour in the Carbro positive made from it. Hence it is of vital importance to avoid any unwanted veiling of the bromide print, whether it be due to over-exposure or to working with an unsafe dark-room light.

Let it be supposed that a portrait has been taken of a man with a stiff white collar, the highest light of which should be white. If one of the bromides is slightly veiled over at this spot, to an extent possibly immaterial in a black-and-white print, it may well matter very much in colour Carbro, for there would be a tint of colour instead of a white high-light in the finished print. Therefore, every care must be taken in making the bromide prints, for if these are faulty it is useless to expect a first-class result.

When purchasing the bromide paper for making trichrome prints, it is advisable to buy it in the roll. It is slightly cheaper to do so, but more important is the fact that paper when wetted expands more in one direction than in the other. In packets, the bromide paper is cut in the way in which most waste is avoided, and one cannot be certain that all pieces have been cut in the same direction. Consequently, one may produce three perfectly good colour positives and then find that, owing to neglect of this precaution, it is impossible to get accurate registration. The bromide paper may be procured in rolls 8 in. wide and 10 or 25 ft. long. These will cut into pieces 8 × 6 in. or 10 × 8 in., which are convenient sizes for enlarging. The time taken by the process warrants the slight extra expense involved in working in these sizes in preference to smaller.

If care is taken in the exposure of the negatives, and their

development is carefully standardized, a single type of bromide paper may be found sufficient, that with a smooth, not glossy, surface and giving normal contrast, for a reasonable amount of control of contrast is possible when making the Carbro positives; but occasionally it may be necessary to use a paper giving softer or more " contrasty " results than the normal, in order to get the desired quality in the bromide print. It should be added that it is seldom possible to " ring the changes " on the variety of the paper in any one set of prints, as very often the paper base itself varies and expands differently, preventing registration.

With regard to the developer for the bromides, either metol-quinol or amidol may be used, but the same treatment must be given to each print. An acid-fixing bath should be employed.

The Bromide Prints

Before beginning work upon the actual bromide prints, from which the Carbros are to be made, a contact print should be made from the negatives in order to see if the negatives are correctly balanced. If separate negatives have been made these should, if possible, be printed in a large printing frame on a single sheet of paper. This will ensure that all three have precisely the same exposure and development. If it is not possible to print them in this manner, great care must be taken that all receive exactly the same treatment. (Here is a point where the Repeating Back scores, with all three negatives on one plate.)

Should the negatives be large ones it is not necessary to make full-size prints from them, but a part should be selected which includes the neutral grey wedge mentioned in the chapter dealing with the exposure of the negatives (p. 29). If no wedge has been employed, then the portion selected should contain a high-light and some object of which the colour is known.

When these test prints have been developed and *fixed*, they

should be carefully examined in white light, and the appearance of the wedge should be noted. If this is not the same in each print, trial exposures for longer or shorter periods must be made until the desired result is attained. For a neutral grey, or black, or white object should appear the same, irrespective of the filter through which the negative was made.

In the case of an object of known colour being selected, the balance of the prints should be compared. If, for instance, the object is a human face, we know that the average complexion is depicted by a fair amount of yellow, about the same amount of red, but only sufficient blue to give modelling. In the high-lights of the face, therefore, there should be hardly any blue at all, while the shadow parts should be a very delicate series of half-tones. The bromides should be examined with these remarks in mind, and any necessary adjustments made in exposure.

Great care should be taken not only in determining the correct balance of the three prints, but also in arriving at the exposure governing the general strength.

Making the Actual Bromide Prints to be Used

It is best to start with the blue bromide print, i.e. the one made from the red filter negative, and just sufficient exposure should be given to veil the half-tone which is most nearly white. If there is anything that should actually be white, the exposure which will *just* leave this so, should be given. It is advisable to make a test exposure first. Begin by exposing the whole piece of bromide paper for, say, 10 seconds; then cover about a quarter of it with card, and give another 10 seconds (that is, 20 from the start); cover up another quarter and give 20 more; cover up again and give 40. The experienced worker, who has some idea of what the correct exposure is likely to be, may prefer to expose the test strip in 5 seconds' sections.

The strip should then be developed for the full time (probably 2½ minutes) and put straight into an acid-fixing bath

without rinsing, and fixed for 2 or 3 minutes before the white light is turned on. It should be examined in the *white light* and the best exposure selected. This should be given to the full-sized print, and before developing, the letter B should be marked on the back, and also the exposure given, and a letter indicating whether normal, contrasty, or soft paper was used. This is for future reference.

When a little experience has been gained it will not be necessary to make test strips for the red and yellow bromide, since, as soon as the blue has been determined, the appearance of the other two in the contact prints will give a sufficient indication of the increase or decrease in exposure necessary to bring them into harmony with the blue one. These prints should be marked with R and Y and with the other details mentioned for the blue. The prints should then all be developed, either together, or if this is inconvenient, for exactly the same time.

The same developer should not be used for more than one set unless a very considerable quantity is being used.

When the actual bromide prints to be used are being made, a white margin about a quarter of an inch wide should be secured if at all possible, as this materially helps to prevent the frilling of the Carbro positives when these are developed.

It must not be assumed, because advice has been given for dealing with variation in the bromides, that this variation inevitably occurs. It does not. Indeed, when experience has been gained in exposing the negatives, the exposures of the bromides will, more often than not, be equal; but whether this is the case, or whether adjustment is needed, the time taken to secure the best bromides possible will be well spent.

In exposing the bromides it is to the high-lights that most attention should be paid. The shadows, except in the case of very flat or violently contrasty negatives can be left to look after themselves. Unless they are hopelessly buried, the shadow portions can be lightened; or, if necessary, they can

be increased at will by varying the time of immersion of the Carbro tissue in the control bath.

As mentioned earlier, when the negatives are of such a type that the bromides from them on normal paper lack quality, then recourse must be had to a different variety of bromide paper, either soft or vigorous, according as the negative is too hard or too soft.

During development it is advisable to keep the bromide paper face downwards, for it must be remembered that the best safe-light will fog sensitive materials if these are exposed unduly to it, and fog is fatal to brilliant results.

As stated before, the prints should be fixed in an acid-fixing bath (a formula is given with all makes of bromide paper) and they should be put straight into this without first rinsing them in water. After proper fixing they should be washed in running water for an hour. In districts where the water is very hard (i.e. the lime content is high) the prints should be given a 3 or 4 minutes' immersion in a 2 per cent bath of glacial acetic acid (i.e. ½ oz. glacial acetic acid, 25 oz. water), the surface being swabbed over with a piece of cotton wool. This will remove from the prints any deposit of lime, which is the cause of loss of high-lights and uneven markings in the Carbros. The prints should receive a further 10 minutes' wash in running water.

They may now either be used at once for making the Carbros, or they may be dried before use, in which case they must be soaked in cold water for 10 minutes.

It is not essential that the acetic bath should be given immediately after washing; there is no objection to it being given after the prints are dry. Ten minutes' washing in running water should be given before using them. Before immersing them in the acetic bath they should be soaked in cold water for a few moments, to prevent undue absorption of the acid by the prints.

Should there be any blemishes on the bromide prints, such as might be caused by pinholes or scratches in the nega-

tives, they may be removed with a sharp-pointed knife. An ordinary pointed nail file will serve extremely well if one side of the point is ground to a slant forming a chisel edge. This will be found efficacious in removing the blemishes or in lightening them; for, if the edge is kept keen, thin parings can be removed from the surface of the emulsion. It is much easier to remove blemishes from the bromides, which serve for several Carbros, than to do so from the finished print, for it is easier to fill in light spots with a brush than to remove dark ones.

It will now be assumed that the various operations outlined have been carried out, and that the bromide prints are ready for the process of making the Carbros from them.

Making the Carbro Positives

Waxing the Celluloids.—Before anything else is done, the three sheets of celluloid on which the Carbros will be developed, should be waxed. It is convenient to pin each by the four corners to a board with drawing pins. A small piece of cloth, 3 or 4 in. square, should be dipped in petrol (or preferably benzol mixture) and rubbed well on to the waxing compound (equal parts of white beeswax and spermaceti wax melted together) so that plenty of wax is taken up on the cloth. This is then rubbed well over the entire surface of the celluloid, care being taken not to leave any part unwaxed, and then a clean, soft piece of cloth is used to polish it off. The polishing must be done very thoroughly so that no traces of the wax can be seen. The celluloid sheets are then set aside in readiness.

When the celluloids are quite new and very highly polished, they should be washed with a slightly abrasive soap such as Monkey Brand, or Vim, which will give a slight tooth to the surface and help to prevent frilling of the positives during development. Very rough abrasives should be avoided, as these may actually scratch the celluloid. The celluloids must, of course, be perfectly dry before they are waxed.

Laying out the Bench.—Next the bench should be laid out in readiness. A dish of cold water should be placed at the back of the bench and the bromide prints put into it face downwards in the order in which they will be used, i.e. normally, yellow at the bottom of the dish, then red, and blue on top. The reason for using a definite order is explained later. Another dish rather larger than the colour sheets (Carbro tissues) should be placed at the left of the table. Next to this a sheet of glass, also larger than the tissues, should be laid, at the end of which a folded cloth should be put, on which to dab the flat squeegee. Next to the glass another dish should be set, and, to the right of this, three pieces of glass a little bigger than the bromides should be placed in readiness for these; while a second piece of cloth should be folded and laid in readiness, on which to dab the squeegee at a later stage.

Stock Solutions: Baths

If not bought ready prepared, the two stock solutions should be previously compounded in readiness, the formulæ being:

Carbro A. Stock Solution

Potassium ferricyanide	1 oz.
Potassium bromide	1 ,,
Distilled (or boiled) water to	10 ,,

For preparing No. 1 bath

Carbro B. Stock Solution

Potassium bichromate	180 gr.
Chromic acid	45 ,,
Chrome alum	200 ,,
Distilled (or boiled) water to	10 oz.

For preparing No. 2 bath

To prepare No. 1 bath, a sufficient quantity to cover well

the three-colour sheets should be made up in the proportion of:

Stock solution A	2 oz.
Water	8 „

Similarly the proportion for No. 2 bath is:

Stock solution B	2 oz.
Water (distilled or boiled if tap water is hard)	8 „

With some makes of bromide paper, it is difficult to get delicate positives, and a modified B solution may be used, with the formula:

Carbro B. Stock Solution, for delicate results

Potassium bichromate	180 gr.
Chromic acid	40 „
Chrome alum	100 „
Distilled (or boiled) water to	10 oz.

For preparing No. 2 bath

The proportion for No. 2 bath will then be:

Stock solution B (modified)	3 oz.
Water	7 „

Alternatively, if it is inconvenient to use distilled or previously boiled and cooled water for preparing No. 2 bath, the effect of the lime in the water may be counteracted by using slightly more of stock solution B, say an extra $\frac{1}{4}$ oz. The exact amount would have to be arrived at by experiment.

A similar quantity of a mixture of equal parts of methylated spirit and water should be prepared so that it can cool down in readiness for use later.

Record Book.—If it is the intention of the worker to take up Trichrome Carbro seriously, it is advisable for him to systematize his procedure, and if he will go further and keep actual records of his working times, &c., it is then possible to duplicate the colour prints with a very reasonable degree of accuracy. It also materially assists in correcting slight

errors in colour when making a second print from the bromides. An exercise book should be procured and ruled out into columns as under:

Left Page. *Right Page.*

Title of Print.	Colour Sheets.	Time put into No. 1 Bath.	Time in No. 2 Bath.	Time on Bromide.	Time on Celluloid.	Developed at	Remarks.
Wall-flowers	*B	12.10	30 sec.	12.15	12.22	12.30	O.K.
	R		30 sec.			12.33	O.K.
	Y		20 sec.			12.36	Too contrasty *

* An explanation of this will be given later.

A clock or watch with a large seconds hand should be laid on the table so that it can be readily seen.

A few sheets of blotting-paper should be placed handy, together with a roller squeegee, preferably as long as the width of the colour sheets it is intended to work (i.e. for 10 × 8 in. prints the roller should be 8 in. long). Everything should now be ready.

Commencing Operations: The Colour Sheets

The colour sheets, as it will be convenient to call them, should always be *at least* half an inch longer each way than the bromide prints. They should be immersed at 1 minute intervals in the No. 1 bath, in the order previously decided upon, normally B. R. Y., the time when the first is put in being noted in the appropriate column of the record book. The insertion of the sheets should be done carefully to ensure that no air-bells are left adhering to their surface. If there are any, they should be removed with the finger tips. If the sheet is first slid in face upwards, and then turned over, air-bells will generally be avoided. When all three are in, the dish should be gently rocked. Just before the expiration of the third minute, the three sheets should be turned bodily over.

They will now be in the proper order for use. The blue one is then removed, drained a moment, and laid face downwards on the piece of glass next to the dish. The surplus moisture is squeegeed from the back in all four directions, the squeegee being dabbed upon the folded cloth after each of the four strokes. The flat squeegee is the one to use.

Colour Sheets and Bromide Prints

The colour sheet is then slid face upwards into the No. 2 bath, avoiding air-bells, and the dish rocked well in both directions. Immediately it is in the bath, the appropriate bromide print (that marked with a B on the back) should be withdrawn steadily from the dish of water and laid face upwards on the sheet of glass placed in readiness on the right-hand side of the No. 2 dish.

At the expiration of the number of seconds it was decided to leave it in the second or control bath, say 30, the left-hand corner of the colour sheet should be taken hold of with the right hand, and the sheet withdrawn steadily from the bath; then without draining laid face down upon the bromide print, the left edge of the colour sheet being placed just clear of the bromide and pressed firmly upon the glass with the finger and thumb of the left hand, while the rest is lowered quickly upon the bromide. Then, with the flat squeegee in the right hand, a firm stroke is taken from close against the finger and thumb of the left hand away to the right.

Next the glass is turned round, the overlapping edge of the colour sheet again pressed firmly with the left finger and thumb, and a second stroke taken as before. A third and a fourth are taken at right angles to this and in opposite directions to one another, so that the " sandwich " has now been squeegeed in all four directions. It is left on the glass and placed out of the way (preferably out of strong sunlight or draught) while the other two are dealt with in a similar manner, the time for the first being noted in the record book.

The control or No. 2 bath should now be thrown away, as

even the small amount of No. 1 brought in by the colour sheets is sufficient to bring about a change in the composition of the bath. The No. 1 bath can be used over and over again. The methylated spirit and water already mixed should be put into the empty dish.

After the blue colour sheet has been in contact with the bromide for about 5 minutes, it should be peeled off and immersed in the methylated bath for 1 minute. (In very warm weather this may be increased to 1½ or even 2 minutes.) The bromide print should be put into cold water for washing and redeveloping later.

A sheet of celluloid is laid on a piece of glass, waxed side uppermost, and the blue sheet laid face downwards, without draining, upon it. It is held down with the left hand as described before, and squeegeed in the same manner. A sheet of blotting-paper is laid on it and it is again squeegeed, this time with the roller squeegee. With the blotting-paper on it it is placed on one side while the red colour sheet is dealt with similarly. (The time is again noted in the proper column of the book.) This red sheet is placed on top of the blue one while the yellow one is dealt with. This, too, is laid in the same fashion upon the other two, and they are left so for about 10 minutes.

Developing the Colour Positives

Two rather large dishes should now be filled with warm water (about 108°), and when the 10 minutes have elapsed, the celluloid with the blue colour sheet on it should be put into the warm water. The correct method of doing this is to hold the celluloid so that the colour sheet is *beneath*; then put one corner into the water, bending the celluloid so that it is bow shaped, with the paper backing of the colour sheet on the outer side of the curve, and going into the water first. With the fingers of the left hand, it should be pressed gently under the water, working from one end of the celluloid to the other.

The object of proceeding in this manner is to bring the warm water into contact with the soluble layer of gelatine between the paper backing and the actual image, and start melting that first. This method has been found a certain corrective for the hitherto inexplicable frilling away of large portions of the image, which quite often happened when dealing with large prints.

As soon as the celluloid is under water, air-bells will be seen forming in the pigment; the celluloid should then be turned over and the paper backing carefully peeled off and thrown away. The celluloid should be given a lateral shaking movement under the water, and lifted out at intervals to allow the soluble gelatine and pigment to run off. When no more colour can be seen coming from it, it should be given another rinse or two in the second dish of clean warm water, followed by a final rinse in cold water, and then pinned or clipped up to drain.

The red and yellow colour sheets are treated in exactly the same way.

The backs of the celluloids should be laid on the blotting-paper to remove drops of moisture, and then pinned on the boards again, in order that they may dry flat.

Single and Double Transfer of Colour Positives

There are two methods of combining the three positives, called single and double transfer.

With single transfer, unless the precaution has been taken of making reversed bromide prints by placing the glass side of the negative to face the lens in the enlarger, the finished colour print will be reversed from right to left. In addition to this disadvantage, registration is more difficult than in the other method, and only very smooth paper can be used for the result.

The worker is strongly advised to work the double transfer method. It has everything to commend it, and only one short extra operation is necessary. An almost unlimited

choice of final support is possible, beautiful papers, glass, ivory, wood, or even silk can be used. For these reasons, " double transfer " will be described.

Should it be desired to try the single transfer method, the only difference is that the order in which the colour positives are picked up on the paper support is reversed; the yellow being transferred first, then the red, and the blue last, it being essential that the yellow image should be beneath the others, owing to its opacity.

Double Transfer of the Colour Positives

In double transfer, a piece of " soluble temporary support " (thin paper, coated with soluble gelatine, rather larger than the colour images) is soaked in *cold* water for 5 minutes to allow it to expand fully. The celluloid bearing the blue image is then placed in a dish of cold water and the S.T. support is laid over it, gelatine side against the blue image, care being taken to avoid air-bells forming between; the two are withdrawn from the water together, the water being allowed to drain from them for a moment. They are laid, with the paper uppermost, on a sheet of glass and carefully squeegeed by the method already explained, followed by blotting-paper and roller squeegeeing. They are then pinned on the board again and allowed to dry.

If the image is moderately thin and it is put in a warm dry place, as on the mantlepiece above a fire, or before a fan, it will dry off in about a quarter of an hour. It must be allowed to get thoroughly dry, when the paper will peel off the celluloid of its own accord, bearing the blue image on its surface. This must now be rubbed gently with two or three tufts of cotton wool dipped in benzol mixture, in order to remove every trace of wax brought from the surface of the celluloid. The cotton wool treatment should be followed by polishing with a soft clean cloth. If every trace of wax is *not* removed, there will be difficulties in getting the subsequent images to adhere properly to the blue.

In passing, it may be stated that a very pure benzol is *not* desirable, as it is so volatile that before the cloth has taken up the wax dissolved in it, the benzol has evaporated, and the wax is redeposited.

When cleaned, the paper should be immersed in cold water, together with the red image on the second celluloid. A minute or two's soaking is sufficient this time. The two are withdrawn, as before, and allowed to drain a moment. The celluloid is then turned so that both images can be seen, and the paper moved about until fairly accurate registration has been obtained. The celluloid should now be laid on a sheet of glass, with the paper uppermost, and, the edge being held by the finger and thumb of the left hand, it should be given one careful light stroke with the squeegee. Movement of the paper should be avoided. The celluloid is then turned over and the result examined.

If movement has occurred and the registration is bad, the celluloid and paper should be placed in the dish of cold water again, the paper peeled off and the operation carried out again; should, however, the registration be fairly good, they should be laid upon a sheet of blotting-paper on a flat surface with the paper underneath.

The image should then be examined and if registration is not perfect, but there is an overlapping of red to be seen, then the celluloid should be very gently pushed with the finger tips in the direction in which the red image should go. The red image, being on the celluloid, naturally moves in the same direction as this is pushed, while the paper support of the blue image adheres to the rough surface of the blotting-paper, and so it is possible to secure very accurate registration. Local as well as general registration can be dealt with in this way, as the paper is of sufficient elasticity to permit a certain amount of local stretching to take place.

The present writer, in actual practice, uses a watchmaker's magnifying lens of about 4 in. focus with which to go over the registration. Anyone who finds difficulty in holding this

type of lens in the eye can adopt the plan of Captain Owen Wheeler and have an old pair of spectacles fitted with a magnifying lens in place of one of the normal lenses.

When registration has been secured, the sheet is turned over, a piece of dry blotting-paper is placed on it, and it is *very* carefully squeegeed with the roller. It is then pinned on the board and put to dry again.

When it is dry, the operations described are carried out again with the yellow positive. When this has been done, a piece of final transfer support paper, of which there is a very wide range, is soaked in water for 10 minutes or longer, according to the thickness of the paper. The thicker the paper the longer the soaking, the object being to secure full expansion.

When the soluble temporary support has peeled off the celluloid, bearing the three images upon it, it again has every trace of wax removed. To make doubly sure, the benzol may be followed by methylated spirit on a tuft of cotton wool, and a polish with a clean cloth; this is not usually necessary, however.

The support with the composite image is then soaked in cold water for not more than 2 minutes, and the image brought into contact with the coated surface of the final support. The combination is withdrawn, laid on a sheet of glass, and very firmly squeegeed, first with the flat squeegee and then under blotting-paper with the roller. It is then placed under the pad of blotting-paper for 10 or 15 minutes, after which it is slid into a dish of water at about 108° which has been prepared. After about a minute, the soluble temporary paper backing can be lifted at the corner, peeled off and thrown away.

The coating of soluble gelatine left on the surface of the print should be removed by gentle laving with the finger tips. It should then be placed in cold water for a moment, and hung up to dry. If it is desired that the print shall have a perfectly matt surface, care must be taken to see that *all*

the soluble gelatine on the surface has been washed away, and then the print must be permitted to dry slowly.

If highly-glazed prints are required, they may be obtained by working the single transfer method, observing, however, that the celluloid on which the blue image is developed is highly polished and free from scratches. If the single transfer method is adopted, a quite pleasing surface can be obtained on the soluble temporary support paper, if it is thoroughly soaked in cold water after it has peeled off the celluloid. It is advisable, if this method is adopted, to harden the finished print in a weak alum or formalin bath, otherwise, should dry mounting be attempted, the soluble coating on the paper might give trouble.

Time Required for the Carbro Process

It may be well to point out that, although from the somewhat detailed explanation of procedure that has been given, the process may appear to be a somewhat lengthy and complicated one, it is *not* so in practice. From the moment of immersing the colour sheets in the No. 1 bath, to that of pinning the third positive up to dry after development, not more than half an hour need elapse; indeed, when it is desired to keep the prints on the light side, the whole operation can be cut down to less than 20 minutes, so that it will be realized that once familiarity with the procedure has been acquired, it is considerably quicker than monochrome Carbro and compares very favourably with most photographic processes.

The discouraging estimates sometimes given of the time taken to produce a finished print—it has been stated in print that 48 hours are necessary—are erroneous. In favourable drying weather, the whole print can be assembled and finished, even with double transfer, in less than 3 hours, and that without any special drying apparatus; and with the aid of such apparatus the present writer has on several occasions at demonstrations produced the finished print under 2 hours.

It will be noted that details given for squeegeeing are very

full. This has been done purposely, as it is important that care should be taken with this operation. Although the details may be modified to suit individual preferences, the important point is that whatever method is adopted, it should be carried out in an absolutely identical manner every time squeegeeing is done, because if it is *not*, the tissues, &c., are stretched in different directions and registration at a later stage may be impossible. It should also be emphasized that the squeegeeing should be carried out with a fair amount of steady pressure.

It will be as well to explain why a certain definite order should be observed in applying the colour sheets to the bromides, and also the effect of varying the time of immersion of the sheets in the No. 2 or control bath. It should be understood that from the moment the colour sheet is in intimate contact with the silver image of the bromide, until it is actually developed on the celluloid, the process continues by which the soluble gelatine of the tissue is rendered insoluble. The new image, that is to say, is in a state of growth. This is one of the reasons why it is so necessary to standardize working methods when duplication is desired; also it explains the reason for noting the order of use in the record book, for if the finished print is, say, too weak in blue, this may be corrected in making a second print by working the colour sheets in the order of red, blue, yellow.

Further, it will be noted in the column headed " Remarks " in the example given on p. 46, that a note is made that the yellow image was too contrasty. This would be due to an error in judgment in deciding to give 20 seconds to the yellow tissue in the control bath. In the second attempt, the yellow should be immersed for 30 seconds, or even longer, should it be thought necessary.

It will be gathered from this that in practice the worker should examine his bromide prints before soaking them, and make up his mind whether he has, after all, got them well balanced, or whether (this, of course, comes with ex-

perience) some modification would be advisable. If anyone of them looks somewhat strong generally, he will proceed to deal with that one first. Should one look somewhat too contrasty, he will note, in the column of time in the control bath, a longer period for this one than for the other two; conversely should it be somewhat flat, he will shorten the time of immersion. These times should be decided upon and written down *before* starting operations.

Redevelopment of the Bromide Print

The bromide print should be thoroughly washed in running water for half an hour, and then redeveloped in a plain metol developer. This should be in a rather dilute form, as otherwise there is at times a tendency for some papers to blister. Metol is preferable to amidol, as not only does the latter stain the print (though this is not important) but the Carbros made from bromides redeveloped in amidol get progressively weaker. Those redeveloped in metol do not suffer from this defect, and it is possible, provided the bromides do not get damaged, to make at least four or five Carbros from them.

It is advisable to give them a brief immersion in the acetic bath, gently swabbing the surface with cotton wool; for even if, as some workers contend, the first immersion in this is sufficient to deal with any further likelihood of lime deposit, one still has a deposit of developer sludge to contend with, which will cause patchy markings, and it is wiser to make quite sure of freedom from this trouble by using the bath.

Should any frilling occur during development, as sometimes happens in very hot weather, the celluloid should be at once removed from the water, and passed through the methylated bath which was used before squeegeeing the colour sheet on to the celluloid. It will be found possible then to finish developing in this, without the frill spreading. As the frilling trouble mostly occurs during hot weather only, it is thought to be due to the greater absorption of water by the gelatine.

A longer immersion in the spirit bath will usually prevent it, as the spirit displaces more of the water in the gelatine.

Occasionally, after development has been completed, the film will be found to commence wrinkling up in the shadow portions. This usually denotes that the wax on the celluloid was not sufficiently well polished off. A camel-hair brush dipped in neat methylated spirit should be applied to the part, when the wrinkle will be found to disappear. The camel-hair brush and methylated spirit is a friend in need on many occasions, for if through carelessness the delicate film is damaged and rolls back, it can often, with the help of the brush dipped in spirit, and a little care, be persuaded to return to its proper position, and an otherwise spoiled picture may thus be saved.

Should the red image predominate in the finished result, it is possible to reduce this chemically. The print should be soaked for a few minutes in cold water. A weak solution of potassium permanganate should be prepared (its exact strength is immaterial—the solution should be a fairly strong pink); a few drops of weak sulphuric acid should be added to this, and the print immersed in it for a few moments. A second bath of potassium metabisulphite should be prepared (a few crystals in 20 oz. of water), and, after a brief rinse in cold water, the print should be immersed in this to stop the action of the permanganate and to clear away the stain. If the reduction is insufficient, the print should be rinsed in running water and the operation repeated. The permanganate solution must be freshly prepared for each print—it will not act if it becomes turbid. A final wash of 5 minutes in cold water should be given.

As a more definite guide to a suitable strength for the two baths, the following formulæ may be given:

Bleaching Bath

Potassium permanganate	10 gr.
Sulphuric acid	20 drops
Water	20 oz.

Stop Bath

Potassium metabisulphite	50 gr.
Water	20 oz.

Up to the present, no satisfactory means has been discovered of chemically reducing the yellow or the blue. It is possible, however, to reduce the yellow slightly by rubbing with a fine abrasive, such as very fine pumice, and a tuft of cotton wool, provided this is done *before* the print is transferred to the final support, i.e. while the yellow is on top. Similarly the blue image can be dealt with *after* transference. In both cases, of course, the print must be perfectly dry, but it must be confessed that at best the procedure is not very satisfactory.

Methods of Transferring the Print

An attractive method of dealing with the print in double transfer is to trim the finished print on the temporary paper support to the desired size, and then to use a large piece of final transfer paper to serve both as mount and support. Prints transferred in this way to some of the rougher papers, such as the Autotype No. 202 transfer paper, or any of the hand-coated papers, look extremely effective. They can, if this is desired, be plate-sunk afterwards. The only precautions to be taken if this plan is adopted is to make doubly sure that every trace of wax has been removed before the application to the final support; and then, when transferring, to immerse it in the warm water with the temporary support underneath, and if possible let it drop off into the hot water of its own accord, or at any rate, with as little handling as possible.

If the print is to be transferred to glass or any other support, the support must be given a substratum of gelatine, which must be hardened and washed well before transferring the picture.

Failures, and How to Avoid Them

Frilling.—The colour positive when being developed on the celluloid, wrinkles up and frills off the celluloid. This sometimes occurs in warm humid weather. The time of immersion in No. 1 bath should be shortened to 2 minutes, or the time in the methylated spirit bath increased to 1½ or even 2 minutes. The former change being preferable, only in very exceptional circumstances should the time in the spirit bath be increased, as this may cause general veiling over.

Difficulty in stripping backing paper when developing.—This is due to the colour sheet getting too dry before development. It may be caused by new blotting-paper or boards being extremely absorbent. Should this be suspected, they should be damped with a sponge before using them. It may be due to leaving under the blotting-paper too long, or to applying pressure. Weather conditions have to be taken into account, and in dry weather the time may be shortened to 5 minutes or even less.

Patches of small light or dark circles.—These occur when the atmosphere is very humid and warm, the tissue under such conditions becoming very tender during subsequent operations. Even the pressure caused by the formation of the little clusters of air-bells, which can be seen before stripping the backing paper when developing, is sufficient to mark the tissue as indicated. To prevent the light spots, the time of immersion in No. 1 bath should be shortened as much as is practicable, even to 1½ minutes; and excessive drying of the tissue on the celluloid, which causes the dark spots, should be avoided. The temperature of the developing water should be increased 5 or 6 degrees and the paper backing stripped *immediately* the celluloid is turned over.

Irregular dark or light spots.—Irregular *light* spots are caused by air-bells adhering to the tissue when in No. 1 bath. Similar *dark* spots are caused by air-bells adhering when in No. 2 bath. The remedy here is obvious.

General veiling over the whole picture, including the part of the tissue which overlaps the bromide print. This is probably due to sunlight actually falling on the colour sheets when in the baths or on the bromides. Contrary to the general belief, the tissues *are* slightly light-sensitive when wet, after they have been through the baths; and direct sunlight should be prevented from falling upon them.

Insolubility.—Electrical disturbances, such as violent thunder-storms, sometimes render sensitized tissue insoluble, and may sometimes be the cause of trouble due to insolubility of one form or another. Excessive drying on the celluloid tends to produce the same result.

Uneven patches of colour in the finished result.—These are probably due to faults in manipulation, and will disappear when more skill has been acquired. It is for this reason that it is important to note such details as the manner in which the bromide prints should be removed from the water, before laying on the glass to receive the colour sheet. The bromide should be withdrawn steadily from the water, in order to retain an even film of water on its surface; and, for the same reason, the colour sheet should be withdrawn steadily, and laid without draining upon the bromide. If the bromide is drawn out carelessly, it will have patches without water on its surface, and others with water. This alters the dilution of the sensitizing bath on the surface of the tissue, and tends to produce patchy results. For these reasons, the method of working should be systematized, so that each process is carried out in the same manner every time a print is made.

THE DYEBRO PROCESS

A process of colour photography which is closely akin to Carbro, and to which many of the working details given above apply, is the Dyebro Process.

By this method gelatine positives in relief are obtained on unwaxed celluloid supports. By soaking these in the appro-

priate dyes they are used as print plates, and dye impressions are taken from them on gelatine-coated paper, the blue being usually printed first, then the red upon it, and lastly the yellow, the transfer paper imbibing dye from each positive in turn.

Quite excellent results can be obtained by the Dyebro process. It is comparatively easy to make further copies by redyeing the print plates, and should the finished print be lacking in one of the component colours, the dye can be applied a second or a third time to give the necessary correction. This is, of course, a decided advantage, but, on the other hand, it requires fairly constant practice to acquire the manipulative skill necessary to approach the quality given by the Carbro process. This at any rate is the opinion of the author.

The procedure in the Carbro process can be followed as far as the production of the developed images on the celluloids, if we bear in mind the necessity for having the bromide paper cut the same way to ensure registration. There are, however, two notable differences. Firstly, thinner sheets of celluloid are used and these must *not* be waxed. Secondly, the Dyebro tissues do not consist of coloured gelatine, but have a gelatine coating containing a small percentage of grey pigment, the purpose of which is to enable the image to be seen. If there were no pigment present this would be a matter of some difficulty, but the pigment makes it easy to observe the image and to know when development has ceased.

Care must be taken to mark the celluloids in some way so that no doubt exists as to which image is which. This may be done either by punching one hole in the blue, two in the red, and three in the yellow, or else by cutting off one, two, and three corners of the celluloids respectively.

The baths and method described for Carbro work perfectly, but the inventor of this process, Captain Owen Wheeler, F.R.P.S., has stated that he prefers the one bath method for the production of the gelatine reliefs. The formulæ he recommends are those worked out by the author of this work.

Single Bath Method of Making Dyebro Print Plates

The formulæ for the stock solutions and working bath are as follows:

No. 1. Stock Solution

Potassium ferricyanide	1 oz.
Potassium bromide	1 „
Potassium bichromate	1 „
Distilled water	20 „

No. 2. Stock Solution

Glacial acetic acid	1 dr.
Hydrochloric acid (pure)	1 „
Formaldehyde (40 per cent)	10 „
Water (distilled)	12 „

The working bath, which should be made up just before use, is:

No. 1 stock solution	1 oz.
No. 2 stock solution	1 dr.
Water	7 oz.

The Dyebro tissue is soaked in this bath for an average time of 3 minutes. If slightly stronger, more contrasty results are required, the time of immersion may be shortened to, say, 2 minutes, while if slightly softer results are wanted it may be increased to 4 minutes.

If a greater alteration of contrast is required it may be obtained by adding more or less of stock solution No. 2, more No. 2 giving softer and less contrasty results, less No. 2 giving more contrasty ones. In the latter case there is usually a tendency to lose the high-lights if less than 1 dr. is used.

It should be understood that the working bath given above will suit most bromide papers, but occasionally it may have to be modified to suit the particular make of bromide paper in use.

If this single bath is used, only the sheets of glass required for laying the bromide prints upon will be needed, that used for squeegeeing between the first and second baths in the Carbro method being no longer wanted.

After the relief prints have been developed and rinsed in cold water it is advisable to immerse them for 5 minutes in a 5 per cent solution of formaldehyde (40 per cent) followed by a wash of 10 minutes in cold running water.

This hardening renders the print plates more resistant to repeated use, and to a large extent prevents the loss of the more delicate details of the image.

It is necessary, however, to eliminate all traces of the formaldehyde completely, otherwise trouble may arise in the transference of the dye to the transfer paper.

After washing, the print plates should be hung up to dry. When they are dry the dye solutions are prepared according to the instructions issued with the materials, and poured into dishes large enough to take the celluloids.

Dyeing up the Print Plates and Making the Dyebro Prints

The celluloids bearing the Dyebro images are then immersed in the dye baths, taking care to put the image that is to print blue into the blue dye, and so on. It is easy to make a mistake, since there is no colour present in the relief itself, and one must remember to look for the distinguishing marks suggested earlier before putting the celluloids into the dishes.

The gelatine transfer paper No. 120 B should be soaked in cold water until flaccid and fully expanded, a matter of 5 to 10 minutes. It is then laid coated side uppermost on a thick sheet of glass, preferably at the bottom of the sink. Should this be impracticable it may be laid on the table with folded pieces of cloth at the ends of it, as described under the Carbro process. These serve to dab the squeegee upon, and prevent a good deal of mess.

The blue print plate is then removed from the dye bath and washed in running water until free from surplus dye. Both sides of the celluloid should be held under the tap.

It is then laid upon the transfer paper with the dyed image in contact with the gelatine surface of the paper, and squeegeed quickly and firmly in all four directions with the flat squeegee.

After 4 or 5 minutes (the warmer the room the more quickly the dye transfers) the corner of the celluloid should be lifted in order to see if sufficient transference has taken place. If not, the corner should be at once squeegeed down again.

If the image appears sufficiently strong the blue print plate is peeled off and replaced in the dye bath for future use.

The red print plate (or the yellow, it being immaterial which is used next) is then removed from the dye bath, washed in running water, and laid over the blue image on the paper; it is then quickly brought into register and firmly squeegeed as before. Care must be taken to avoid movement of the celluloid after registration has been effected. Registration should be obtained as quickly as possible, otherwise the outlines of the picture will be blurred and diffused. The red image will transfer in about the same time as the blue, the corner of the print plate being lifted to determine when sufficient depth has been obtained.

The operation is repeated with the yellow print plate, and when sufficient dye from the yellow image has been absorbed the result will be the finished picture.

After the transference of each image the transfer paper should be passed through cold water in order to leave on the surface a film of water, which will prevent the formation of air-bells and assist in the registration.

Correcting the Colour Balance

If the finished print is too weak in any colour a second or even a third application of the desired dye plate can be given until the correct result has been obtained. Obviously

it is better to avoid the repetition of dyeing as far as possible since the brilliance of the image will suffer.

As stated earlier, the print plates, after redyeing, may be used for further prints as required, and with practice three or four copies can be made from a single set of print plates in an hour.

Should the transfer paper, bearing the dye images, be permitted to dry it must be soaked in cold water until fully expanded before any further dyeing up is attempted, but it is better to avoid drying between operations.

Should there be difficulty in getting the dye to transfer from the shadow portions of the image, it indicates that the print plate has been overhardened in the formalin bath, or that it has been insufficiently washed after removal from this.

It will be found that this method of making the print plates results in the image of the finished Dyebro print being reversed from right to left. This may be overcome by reversing the negatives in the carrier when enlarging.

If contact bromides are to be made from glass negatives this difficulty can be got over by printing through the back of the bromide paper, i.e. by putting the latter into the printing frame with the base paper against the emulsion of the negative. The exposures made in this way will be about eight times those given when prints are made in the usual manner.

The consequent diffusion of the image has less effect upon the image than might be supposed.

With film negatives, of course, the films themselves should be reversed.

Alternative Procedure

As an alternative to the method of making three print plates as described above, the blue image can be obtained by making a bromide print from the red-filter negative in the usual way (i.e. the right way round, with the emulsion of the paper towards the negative) and toning this with a Prussian Blue Toner, such as Burroughs and Welcome's Blue Toner.

The bromide paper for this purpose must be coated with a fairly soft gelatine emulsion. Illingworth's Rapid Satin or Zelvo answers very well.

If contact prints are being prepared, unless film negatives are in use (which, as stated previously, can themselves be reversed), the bromide prints for the red and yellow print plates must be exposed through the back of the paper as described earlier in order to get them to register with the blue-toned bromide. For the reason given earlier all three pieces of paper must be cut the same way from the roll. In printing the bromide print for the blue image it should be kept rather on the light side, as the toning bath tends to intensify the image considerably. This print forms the base of the final result and if it should have been dried before applying it to the red and yellow print plates, it must be soaked in cold water for at least five minutes in order that it may expand to the same size as the other two images. The procedure is then the same as outlined for the first method.

It must be remembered that in using the toned bromide print as a base a separate bromide print is required for each Dyebro print, hence the first method is usually preferred.

CHAPTER IV

The Screen-plate Processes

The screen-plate processes belong, as has already been explained, to the "Additive" method of colour photography (pp. 13, 14).

At the present time there are two distinct classes of screen-plate processes, the "Combined" and the "Duplicating". Of these the "Combined" can be divided into two types, the Autochrome process—the invention of the Lumière Brothers

—and the Agfa. In the Autochrome process the mosaic screen is composed of dyed starch grains. The other process, the Agfa, is very similar to the Autochrome, but in this instance the mosaic screen is the result of the emulsification of coloured gum solutions, each dye solution being in a vehicle which will not mix with the others. The emulsified mixture of dye solutions is coated upon the plate and dries down into tiny spots of very transparent colour. The emulsion is coated upon this, and the resulting plate gains in both speed and transparency over the Autochrome plate. The Autochrome mosaic screen, composed as it is of the tiny starch grains flattened out under pressure, possesses an appreciable thickness, which if it does not permit of the high speed or quite the transparency of the Agfa, gives to the result a greater richness of colour than is perhaps obtainable by any other screen-plate process.

The "Duplicating" process is represented to-day by the Finlay process. This has a mosaic screen of regular pattern printed in a most ingenious manner in regular squares over a glass plate, which is used as a separate entity. It is put in close contact with the emulsion of a separate negative plate into the dark slide, and the photograph is taken through it.

In this process an even higher speed has been reached than in the Agfa process, and instantaneous exposures of 1/50 of a second have been secured under exceptionally favourable conditions. It possesses, upon the average, even greater transparency than the Agfa plate, making it specially suitable for lantern projection. Its possibilities in ease of duplication put it into a class by itself, as does the fact that monochrome prints can be made direct from the negatives.

Against these advantages, however, must be placed its considerably higher cost, due principally to the difficulties in making mosaic screens of regular pattern. Besides, it is not possible to produce the finished result as speedily and easily as with the Autochrome and Agfa colour plates.

The Compensating Filter

In all three processes which have just been mentioned it is essential to use what is known as a "compensating filter" on the lens—the purpose of this being to "even up" the exposure through the colour dots of the mosaic screen. This is necessary, for although the emulsion used is panchromatic, i.e. sensitive to *all* colours, it is not *equally* so. It is still much more sensitive to blue-violet than to red and green, and if used without a compensating filter for daylight exposures, the portions of the emulsion behind the blue dots would be so much more fully exposed than those behind the green and red that the result would be very much too blue in tint. The compensating filter, however, absorbs this excess of blue light, and so secures equal, or rather, properly balanced exposures behind all the dots. Similarly with artificial light, such as arc-light, flashlight, half-watt, incandescent gas, &c., the spectral composition varies and special compensating filters are required to secure correct colour balance. In passing it may perhaps be mentioned that the emulsion of the Agfa colour plate happens to be of such colour sensitiveness as to be correctly balanced for half-watt electric light (i.e. gas-filled lamps), and therefore no compensating filter is necessary when making exposures by this light. Obviously, for the reasons mentioned in the chapter on three-colour negative making, one must not mix various lights when making the exposure.

The Position of the Compensating Filter

The question whether the filter is to be used in front of or behind the lens of the camera, is of importance, since the position it occupies influences the focussing of the image. It must be remembered that the emulsion of a colour-screen plate when in the camera is *not* in the same position as that of an ordinary plate or film. In both the combined and the duplicating methods there is a thickness of glass in front of

it—that of the separate taking screen in the Finlay process, and the glass of the colour plate itself in the Autochrome and Agfa. In the former instance the taking screen has to be put into the dark slide in front of, and in close contact with, the negative plate, while in the latter the plates are put into the slide with the glass side facing towards the lens of the camera, the reason for this being that in order to get a record of the colours of the object, the rays of light reflected from it *must* pass through the dots of the mosaic screen *before* acting upon the emulsion.

There are three ways of allowing for this alteration of the position of the emulsion, and the position in which the compensating filter is used on the lens comes into the question. It is advisable to determine first which will be the most convenient position for the camera one is going to use, and then adopt one or other of the methods of dealing with the focussing outlined below.

If the filter is to be used in front of the lens and the camera used almost entirely for colour-plate work, then the best way is simply to reverse the focussing-screen, bringing the matt side of the glass to the rear. It is then immaterial whether the filter is in position or not when focussing.

If, however, the filter is to be used at the back of the lens the ground-glass need not be reversed, provided the filter *is not* in position when focussing.

As has been explained in an earlier chapter, the fact that the rays of light, after passing through the lens, have then to pass through the filter throws back the point of focus by approximately the thickness of the glass of the plate, and so allows for the altered position of the emulsion.

The third way is to leave the focussing-glass in its normal position, and, with the filter on the front of the lens, to rack back the lens a distance equal to the thickness of the glass plate after focussing. This way is not to be recommended, as it is so easy to forget to rack back the lens.

With the Finlay process it is possible to obtain the com-

pensating filter in gelatine form, and in that form it may be used between the components of the lens, though this is only advisable either when used for experimental purposes, or if the camera is to be devoted entirely to this process. When the filter is used in this way, either the focussing-glass must be reversed, or the lens racked back after focussing.

As has been mentioned, with a lens of large enough aperture, such as F. 2·9, instantaneous exposures are possible with both the Finlay and the new pattern Agfa plate. For such exposures, a focal-plane shutter is preferable, on account of its higher efficiency in passing light, to the diaphragm-between-lenses type of shutter. With a reflex camera, the filter should be fitted on the front of the lens, and the focussing-screen under the hood, turned over to bring the matt side of the glass on top. With some reflex cameras, however, this is the normal way of fitting the ground-glass. With these a piece of plain glass, the same thickness as the colour plate, must be placed beneath the focussing-screen proper, in order to bring it into the required position.

With a camera of this type under favourable conditions, as with seascapes and similar brightly lighted views, exposures as short as 1/30 of a second can be given with the new Agfa plate and fully-exposed results obtained.

The author has found exposures of 1/10 of a second of a baby in a garden to be quite badly over-exposed, and, although it must be admitted that the light was extremely actinic, this affords a concrete instance of what is now possible with the colour-screen plate.

With the Finlay process under similar conditions even shorter exposures should be possible.

Using the Compensating Filter in Gelatine Form

With reference to the use of the gelatine form of filter, care must be taken, while cutting it to fit the lens, not to touch the surface with the fingers.

The filter should be left in the thin wax paper it is wrapped

in, and the inner side of the lens mount should be pressed firmly on this and rotated. This will leave a circular mark the exact size required. This mark should then be followed round with a sharp pair of scissors, the paper and the filter being cut at the same time. With the point of the scissors, or a pair of small tweezers, the film should be carefully removed from the paper and dropped into the lens cell, and the component which has been removed screwed back again; the filter is now secure from all risk of damage.

As the Finlay filter is a pale yellow-green it will serve as an excellent filter for monochrome photography if used with a panchromatic plate.

One must, however, remember to change the ground-glass of the focussing-screen round, any time an ordinary photograph is taken.

The question may be asked, is it possible to take colour-screen plates with the box or fixed-focus form of camera? It is, provided the filter can be fitted at the back of the lens. The camera is then used in the usual manner, for, as already pointed out, the bending of the rays of light as they pass through the glass of the filter throws back the focus the necessary amount, and so permits the use of this type of camera without any further adjustment.

It should be pointed out that although most types of plate-holders can be used for the screen plates there are some which are unsuitable. This point will be dealt with in its proper place, as it applies to the two types of plate differently.

In all photography it is desirable that the front surface of the lens should be protected in some way from strong side-light falling upon it. More especially does this apply to the modern large aperture anastigmats, which seldom have the deep projecting flange possessed by the older lenses. It applies with even greater strength to colour photography, especially when the filter is employed on the front of the lens.

It is very advisable to use some form of lens hood, for

without it in strong side-light one sometimes obtains a peculiar false coloration of the transparency; moreover, the results lack the brilliance that a good lens hood imparts.

A lens hood can be purchased quite cheaply, but if one is using the filter in a square holder it is very easily made by the photographer.

Making a Lens Hood.

To make a lens hood a piece of black velvet ribbon about 1½ in. wide and a little longer than the four sides of the filter holder combined should be laid with the pile downwards. Four pieces of black card (the cards packed with the colour plates answer well) should be cut the same width as the velvet and the same length as one side of the filter holder. One side of each of these should be spread thinly with seccotine and then laid in a line, sticky side down, upon the velvet, leaving a gap of about 1/10 of an inch between each pair. They should be pressed well down on to the ribbon and covered with a card with a weight on it to dry. When dry, or nearly so, a piece of black ribbon, not necessarily velvet, of the same width and length as the first, should be stuck upon the cards. The whole should then be folded so as to form a square, placed round the filter holder to see that it fits snugly upon it, and the overlapping ends of each piece of ribbon stuck down. The hood can now be folded flat between two pieces of card, taking care that the stuck-down ends of the ribbon are under pressure, and a weight put on top and the whole left to get thoroughly dry.

When quite dry it will probably be found necessary to cut an opening or a gap in one or other of the sides so that it will fit over the projecting clip of the filter holder. Obviously the latter differ in design, but a little ingenuity and a sharp-pointed penknife will produce a very efficient lens hood, which when not in use can be folded flat, taking up very little room in pocket or camera case.

THE COMBINED SCREEN-PLATE PROCESSES

At the time of writing these are confined to the Autochrome and Agfa colour plates. The processes in question are perhaps the simplest and certainly the speediest methods of producing colour transparencies. The results at their best are unexcelled, and their cost is considerably less than that of the duplicating method.

There is one rather serious objection, viz: the fact that only a single copy is obtained; though perhaps this statement requires some modification, for it *is* possible to get reproductions by what amounts to re-photography, but the copies scarcely possess quite the fine quality of the original.

The two processes are very much alike both in the results produced and in the manner in which they are worked, and indeed they are based upon exactly the same underlying principle, but the methods employed in the manufacture differ considerably and present interesting contrasts.

Earlier types of Screen Plate

They are a departure from the first type of screen plate, for both the Joly and the MacDonough, which were the earliest processes in colour photography based upon this idea, used a screen made of parallel lines of the three primary colours; that is to say they used mosaic screens of regular pattern, employing them as a separate plate, as is done in the Finlay process to-day (p. 92).

The Autochrome Plate

The brothers Lumière, however, used the rather unlikely potato as a source from which to make their mosaic screens. Doubtless many of my readers have noticed the fine white deposit that remains at the bottom of the basin in which peeled potatoes have been cut up, when making "chips" for instance. The white particles are, of course, starch grains

from the potato. In preparing the Autochrome plate these are sifted until granules having a diameter varying from ·015 to ·020 of a millimetre are obtained, which are dyed in three lots, red, green, and blue-violet. These coloured powders are then thoroughly mixed, the result being a neutral grey mixture, which is spread upon sheets of glass which have been coated with a sticky substance. The surplus grains are brushed off, leaving the glass covered with starch grains which touch but do not overlap one another. The spaces which necessarily occur between the grains are filled up with black powder, and the grains are flattened out under pressure. The whole is then coated with an impervious varnish. On this an exceedingly thin panchromatic emulsion is spread, to protect which a specially prepared black card is placed in contact with the emulsion, and kept in position until development takes place. The plate is put into the dark slide so that in the camera the glass side faces the lens, the card being left in its position behind the emulsion, protecting it from damage in the dark.

The Agfa Plate

The Agfa screen, as indicated earlier, is prepared in a different manner. Dyed gum solutions of the three primary colours are prepared in mediums which do not mix with one another, but which, when emulsified together, produce a homogeneous liquid, at least in the sense that milk is a homogeneous liquid. Milk, as is well known, consists of an emulsion of fatty liquids and water &c.—fluids which in the ordinary way do not mix as, for instance, spirit and water do, but rather retain their original character in a very finely divided state.

This emulsion of mixed dyes is coated upon the glass plate, and dries down into exceedingly minute dots of coloured gum, of approximately similar size to the starch grains of the Autochrome plate, some three millions of them going to cover one square inch of glass. As there are no interstices between

the dots of colour, no necessity arises for using black powder to fill them; consequently the mosaic screen so produced is rather more transparent than that made with starch grains. This, combined with a faster emulsion, results in a colour plate of about twice the speed of the Autochrome, a speed which, as already mentioned, enables instantaneous exposures to be given.

General Working Instructions with the Autochrome and Agfa Colour Plates

The makers of the Agfa and Autochrome plates issue booklets on their use gratis upon application, so admirably full and explicit that it is impossible to improve upon the instructions contained therein. The details to be given here are of a more general nature, based upon many years' experience and meant to be supplemental to the official instructions. The worker is advised to study closely the instructions issued by the makers of the plate he intends to use.

As the emulsion in both cases is panchromatic, the precautions outlined in the chapter dealing with the use of panchromatic plates must be observed, and if a green safelight is used the plates must be exposed to it as little as possible. It is preferable to load the dark slides in total darkness.

Dark Slides for Use with the Combined Screen Plate

If the dark slides to be used have rather strong springs, these should be flattened out so that they press as lightly as possible on the plate, for despite the presence of the protective card the emulsion is so extremely thin that it is very easily damaged. If the springs cannot be softened it is better to remove them and paste in their place a square of black velvet the size of the plate. If the velvet is used in this manner it is possible to dispense with the black card, though the author prefers to use this also, as chemical dust may settle upon the velvet with disastrous results.

In loading the slides with either the Autochrome or Agfa

colour plate, the plate must be put into the slide so that the glass side will face the lens when in the camera.

Double dark slides are to be preferred, though the writer has used single metal slides for many years with success, but extra care should be taken when inserting the plates to avoid any pressure which may abrade the surface of the emulsion. Before the plates are inserted, the dark slides should be dusted out with a soft brush, and then laid on the bench in a convenient position ready for filling before the light is turned out.

Strongly Coloured Surroundings

When the subject to be photographed is being chosen, care should be taken to avoid trouble from strongly coloured surfaces. If, for instance, a portrait of a lady in a light-coloured dress is to be taken, the sitter should not be placed near a brightly coloured door, nor close to a creeper-covered wall, for the reflection of colour from these becomes exaggerated in the colour transparency, and the side of the face and dress near to it will appear tinged with colour. Another snag to be avoided is the taking of portraits out of doors under a blue sky, for should the sitter have glossy black hair it will appear blue on top. Similarly, water will sometimes take on a stronger tinge of blue than is natural, though this may sometimes be corrected by a slight alteration in the position of the camera.

With the Agfa plate, in such circumstances, e.g. in presence of a deep-blue sky reflected by large areas of water, it is advisable to use the "Deep" instead of the "Normal" compensating filter. The Agfa booklet gives full instructions as to the choice of the suitable filter. It should be pointed out, however, that in the case mentioned, water very often does and should appear blue, whatever the non-colour photographer, who was not present at the time, may say. The writer well remembers the intense blue of the water of Loch Coruisk in the Island of Skye one August day in 1913, and the deep and

pure blue of the water in Lulworth Cove in Dorset on one occasion a few years ago, and it must be confessed that the sceptics make him a little impatient at times. To refuse to see beauty in the brilliant and lovely colours of nature is as reprehensible as to be unable to detect it in the lovely nuances of tint and tone, in the pearly mists of autumn or November.

Composition

The colour worker must be on his guard to avoid being carried away by his ability to reproduce colour, and must refuse to allow himself to photograph it unless it falls harmoniously into his picture. He must look out for the subtle beauties to be found in the more delicate colours, which nature spreads before him as well as the more strident colours in her palette. Those who are able should take advantage of the opportunities offered by art classes, in order to learn how to make the best use of the power that the colour plate puts into their hands.

The time is past when any colour should be photographed, just because it is possible to do so, and workers, for their own benefit as well as for the credit of colour photography itself, should endeavour to raise the artistic standard of their work by studying composition in colour and form as exemplified in the works of art exhibited in our art galleries.

Exposure

With regard to exposure, the reader should study the chapter on the subject, bearing in mind that, with the screen plate of this type, over-exposure is as fatal to success as under-exposure. If exposure is excessive the image will entirely disappear, since, contrary to usual practice, under-exposure produces dense positives, and over-exposure, thin ones.

Development: Temperature

The plates should be developed without undue delay. This does not mean that it is impossible to defer develop-

ment, but it is better not to do so. Should delay be necessary, as for instance when making the exposures on holiday, care must be taken when repacking the plates to keep the protective card in contact with the emulsion, and to pack them so that as little movement as possible can occur.

As regards the development of these plates, temperature is an important factor, and every endeavour should be made to keep the various baths as near to 65° as possible. The makers have experimented with all types of developers, and the formula adopted contains hydroquinone and ammonia, and, as is well known, such a developer has a limited range of activity as far as temperature is concerned, especially with plates of this nature. In hot weather, ice should be used to get the temperature down to the desired level, or failing this, operations should be held over until the weather cools. In very cold weather, if it is impossible to warm the dark-room, one or two bricks *warmed*, not made too hot, in the oven, will retain their temperature for a considerable time. If the dishes are kept on these, the solution may be maintained at the desired temperature.

The Dark-room: Desensitizers

To return now to the dark-room, the worker is advised to adopt the use of a desensitizer as described in the earlier chapters of the book, at any rate at the commencement. As to the continuation of its use, much depends on the purpose in view. If what is aimed at is the production of the finest technical result possible, it is perhaps better not to desensitize. Even when no discoloration is apparent, the use of a desensitizer appears to "clog-up" as it were, the subtle differences of gradation, and affects the brilliance of the result. That this degradation is almost imperceptible is proved by the fact, that if one mixes transparencies of the same subject, one of which has been desensitized and the other not, it is extremely difficult to tell which is which unless they have been marked in some way. Nevertheless it *is* detectable when

one has become accustomed to seeing very fine technical work, and for that reason it cannot be recommended if the finest possible result is required.

On the other hand, if one wants to get the highest average of results from one's exposures, as might well happen where the plate is being employed to make photographs for some special purpose, say for illustrating a lecture on a holiday tour, then undoubtedly it is safer to use the desensitizing bath. To do so will save many an exposure which otherwise would find its way into the dustbin. By its use one can adjust the time of development more easily, and produce the best result the exposure given will yield, which will be better than one can hope to do when working by the time and temperature method in total darkness—or even by the dim light of the special safe-lights employed. With this latter method, after one has accustomed one's eyes to the light, little difficulty will be experienced, but as an aid to the attainment of a sense of confidence and ease in working, there is no doubt that the desensitizer stands one in very good stead.

Of the desensitizers suitable for the purpose, either the Lumière Aurentia, or the Pinacryptol Yellow desensitizer may be used. Some care is needed in the use of the former, because some persons are susceptible to the dye (Aurentia), and in those it may produce a very unpleasant and painful form of eczema. Anyone susceptible in this way should avoid its use. The author, personally, is not sensitive and prefers it to any other desensitizer.

Laying out the Working Bench

If a desensitizer is to be used, then two extra dishes will be required on the dark-room table, one for the desensitizer itself, and one, a fairly large one for choice, to hold cold water in which to rinse the plate briefly before putting it into the developer. This operation is essential, since if the desensitizer is carried into the developer, although it will not inter-

fere with the first development, it will tend to prevent the blackening of the image in the second development, i.e. after reversal, if the same bath is used.

The bench should be laid out as follows: on the left, the dish with a fairly liberal supply of the desensitizing solution; near by, an opaque card for covering the dish; next, the dish containing the cold water for rinsing purposes; then, the dish for the developer; and, finally, the dish containing the reversing bath.

It is very desirable to have running water available for washing the plate after developing and reversing, though should it be impossible to provide this a large bucket of water beneath the table will serve to give a vigorous swirling motion to the plate for one minute between the baths. Where running water can be used, the tap should have one of the "anti-splash" devices fitted to it so that the water runs in a smooth stream. The tap should only be turned on partially, while the plate itself should be held at an oblique angle to the stream of water, otherwise if the force is too great it may damage the emulsion.

A dark-room clock, or a watch with a fairly large plain seconds hand should be placed where it can be easily seen. If no desensitizer is being used, and a transparent green safe-light is employed, the watch can be put inside the lamp (provided an electric one is employed), and the hands can then be easily seen. An alternative method is to use one of the cheap electric torches, taking off the glass lens cap and inserting between it and the lamp-bulb two pieces of the green and one of the yellow Virida safe-light papers, which can be obtained from Messrs. Lumière, the manufacturers of the Autochrome plate. This forms a very handy method of noting the time and inspecting the plate when desired.

Development

We shall assume that the desensitizing bath is being used. In total darkness, the plate is taken from the dark slide, the

black card is removed, and with a wide, soft camel-hair brush, or a piece of folded velvet, the width of the plate, the emulsion is gently wiped across. This is done to remove any dust or particles of the emulsion which the cutting of the plate may have broken off, and which often adhere to the surface. If these are not removed before the plate is wetted it will be found impossible to do so afterwards, and black spots and marks corresponding to them will irrevocably mark the plate.

The plate should then be slid, emulsion side uppermost, beneath the desensitizer. The dish should be covered with the card, the orange or red light turned on, and the time immediately noted.

At the end of 30 seconds the plate should be lifted out and rinsed quickly and thoroughly in the dish of cold water; if close to the light the plate should be shielded from direct rays with the card from the dish, and then put into the second dish.

The dilute portion of the developer, of the strength given in the official instructions, should then be poured on, and the time again noted by the seconds hand of the watch. The plate should then be watched carefully for the first appearance of the image. The general outline of the picture is to be looked for and not such parts as, for instance, the sky in a landscape, or a window in an interior, or the highest lights in a portrait. The time taken for the image to appear having been noted, the dilute developer in the dish should be poured into the measure having the concentrated developer in it, taking care the plate does not fall forward; then the strengthened developer is poured back upon the plate. This method is preferable to taking the plate from the dish, as the less the plate is handled the better. It is obviously important *not* to pour the concentrated developer straight into the dish, as it is impossible to avoid badly marking the plate should this be done.

The makers issue a table for the methodical development of their own particular formulæ, and it is a good plan to copy

out the one applicable to the plate in use, on a grease-proof (or other translucent) paper and paste it on to the glass of the dark-room lamp. It can not only be easily seen there, but it will always be there when wanted, a state of affairs which does not always exist in the photographer's dark-room. This table is extremely useful, for not only does it indicate the correct time to develop the plate, but it also shows what correction is necessary in future exposures to avoid the mistake which must have been made in the present case, should the image not appear at the proper time.

When the proper time has elapsed, the plate is taken from the dish and washed for one minute in running water. If it is held under the tap, observe the precautions mentioned earlier to avoid damaging the film.

Reversing Bath

The plate is then put into the reversing bath for at least one minute before turning on the light. As in all similar cases, while the plate remains in the solution, the dish must be rocked to and fro in both directions more or less continuously, if markings are to be avoided.

When a number of plates have to be developed, it is as well to use two dishes of the reversing solution, and at the expiration of the first minute to slip the plate into the second dish. This ensures the complete "eating away" of black silver image in the minimum of time. This should take place in about two minutes, when the plate viewed by transmitted light will appear clearly in the proper colours. The first bath of reverser should be thrown away as soon as it becomes muddy or greenish looking, the second dish being then used as No. 1, a fresh lot of reversing solution being prepared for the final immersion. The plate should not be left in the reversing bath any longer than is necessary to dissolve the black image, nor should it be handled and looked at unnecessarily. After reversal it is washed again in running water for one minute.

Second Development

The second development then takes place, when the developer used for the first development may be used. Occasionally the plate will be found to have semi-iridescent marks on the surface of the emulsion. These sometimes look very like finger-marks, but the worker is not the cause of them, and the reason for their intermittent appearance is somewhat obscure. When the transparency is viewed by transmitted light they become apparent in the high-lights as light-brown stains and are apt to spoil a delicate slide. It is possible to remove them after the plate has been dried by moistening a small tuft of cotton wool with methylated spirit, squeezing it nearly dry (to avoid any spirit getting beneath the protective varnish and dissolving the colours of the mosaic, these being spirit soluble), and then rubbing *very gently* with a circular motion until the marks disappear. This method needs the exercise of great care to avoid abrading the delicate surface of the emulsion.

A more satisfactory plan is to use an amidol developer for the *second* development, compounded as under:

Amidol	20 gr.
Soda sulphite (anhydrous)	60 „
Water	8 oz.

This is used at full strength, the plate being developed for 2 to 3 minutes until completely blackened. This developer must be freshly prepared as it does not keep for more than a few hours. It is *not* suitable for the first development of the plate.

After-treatment

While as far as possible, after-treatment of the plate is best avoided (for without doubt the technically irreproachable transparency is the result of correct exposure, accurate development and reversal, and speedy drying) yet, as one's work does not invariably result in this most desirable state

of affairs it frequently happens that transparencies can be improved by some after-treatment.

Reduction

If, for instance, the plate has been slightly under-exposed and is rather heavy looking and lacking in brilliance, it may be given a very brief immersion, say 15 or 20 seconds in a weak solution of hypo. The ordinary fixing bath diluted with about three times its own bulk of water will answer. If this does not act sufficiently at the first application, the plate may be put in a second or a third time. The plate must have a full 2 minutes' wash in running water after this treatment before drying.

This method answers well, if the reduction required is slight; if a greater amount is required, a weak bath of Farmer's Reducer should be given. This is prepared by adding a few drops of a 10 per cent solution of potassium ferricyanide to the hypo solution (above) until it is a pale yellow colour. The plate is immersed in this for a few seconds, rinsed under the tap, and *then* examined. It should not be held up with the reducing solution on it, as the action will proceed and may ruin the plate. When sufficiently reduced the plate is washed for 2 minutes as before. The mixed Farmer's Reducer should be used immediately it is mixed, as it does not appear to retain its power of reduction for long, especially after it has once been used.

The author has found this method of reduction preferable to the weak solution of the reverser which is sometimes advocated, for if this latter is used it is impossible to intensify the slide afterwards, should reduction be carried too far, since the image turns brown upon intensification and the colours are ruined.

Intensification

For intensification the author prefers the "Agfa" Mercurial one-solution intensifier. It is extremely simple to use,

the immersion of the plate for a few seconds is all that is required, and as far as permanency is concerned, plates which have been intensified in it some five or six years prior to the time of writing show no signs of fading or change of colour despite their frequent use in the lantern for projection purposes.

Varnishing

It is advisable to varnish the plates before binding them with a cover of glass. Spirit varnishes must *not* be used, as they will dissolve the dyes of the mosaic.

The author prefers the following formula to that recommended by the makers either of the Agfa or the Autochrome plate. The former is rather too thin and is apt to leave streaky markings, while the Autochrome varnish is somewhat thick.

Colour Plate Varnish.

Gum damar	10 parts.
Crystallizable benzol	100 ,,

Varnishing appears to be a somewhat tricky problem to many workers, who find it difficult to prevent streaks from showing. The best method of avoiding these is, first to have a fairly large bottle of varnish of a circular shape so that it will stand firmly on the bench. The plate should be balanced emulsion side up on the tips of the fingers of the left hand in a horizontal position. A pool of varnish (a reasonably large amount) should then be poured into the centre of the plate, and the bottle placed in a convenient position on the table. The plate should then be tilted very slightly, first towards one corner and then towards the next, so that the varnish flows evenly over the plate; tilting finally to the corner nearest to the wrist, and then letting the surplus run into the bottle again. Just before it has all run in, the plate should be rocked gently from side to side, while held with the thumb and third finger of the right hand, the movement being lateral and not backwards and forwards, and continued until no more

varnish runs from the plate. In this manner streaky markings will be avoided.

Binding

The next step is that of binding up with a cover glass. If the transparency is intended to be used in a lantern for projection—the English size for this purpose is $3\frac{1}{4}$ by $3\frac{1}{4}$ in., while the American is $3\frac{1}{4}$ by $4\frac{1}{4}$ in.—the cover glass must be of the same size as the transparency. If the transparency is not intended for lantern projection, but for viewing in the hand, a much better plan is to make the cover glass considerably larger than the transparency itself. This gives little more trouble, and yet shows the picture off to very much better advantage, as an opaque margin of about an inch or so isolates it from the surrounding light.

For the normal method of binding, the special tape for use with the heating iron supplied by the makers of the Autochrome is admirably suited, and preferred by many workers. By its use no moisture gets at the edge of the plate. This is an advantage, for sometimes, if the gummed tape is used and too much moisture is applied to it, there is a tendency for the moisture to attack the colour grains and cause a spreading of colour in towards the centre of the plate, should it be put into the lantern before the binding is thoroughly dry.

In using ordinary gummed tape it will be found convenient either to use the slips ready cut the full length of the four sides, or to cut it that length from the roll, rather than to use the short $3\frac{1}{4}$-in. stripe. The gum should be moistened —the author has not yet come across a more convenient method than the use of the tongue—and the strip laid out on a piece of blotting-paper or a folded newspaper, the gum of course being uppermost. The transparency and cover glass, which should be well polished and thoroughly dry, are now taken and squared off between the fingers, and the lower edge of the two is pressed firmly into the centre of the tape close to its end. The plate is then turned through a right

angle, and the next edge pressed down in its turn. At the same time the finger and thumb are run down the first edge (which will be found to have the tape adhering to it) so as to press the edges of the tape down upon the sides of the glass —not, however, pressing the extreme corners, which should be left projecting.

The plate should be turned over and over until all four edges have had the tape thus applied to them. The projecting corners should then be cut off as close to the plate as possible with a sharp pair of scissors, and the tape rubbed well down with a soft dry cloth.

Care must, of course, be taken during these operations to ensure that the tape is pressed on evenly, with its edges parallel to the sides of the plate, so as to present a perfectly square opening. Nothing looks worse upon the lantern screen than a carelessly bound lantern slide with sides uneven or ragged, and many a slide which otherwise might have received the judges' award at a competition has been thrown out because of its slovenly appearance.

Masking

After binding, the transparency should be carefully inspected to see if the composition can be improved by masking off any part of it. This may very well happen, the reason being that the lens includes more than the eye *looked* at (not saw) when taking the photograph. While it is possible, when binding transparencies made by the combined processes, to put a mask inside, it is by no means an easy matter; for it is not possible to see the picture when it is laid on a sheet of white paper, as can be done with monochrome lantern slides. It is therefore permissible to mask these transparencies on the outside. If the amount of masking is small it can be done with strips of the binding tape, so long as care is taken to see that the top and sides are at right angles to each other, and that the opposite sides of the opening that is left are parallel.

Spotting

Transparencies intended for the lantern should be properly "spotted", i.e. two circular spots of gummed paper (which can be bought ready for use from photographic dealers) should be stuck upon the front top edge of the slide. The spots should be about $\frac{3}{4}$ of an inch from each end, and should not show when the picture is projected upon the screen

Standardization of Sizes

With regard to a method of mounting transparencies intended for viewing in the hand, the plan now being adopted by some of the principal photographic societies, including the Royal Photographic Society, is to recommend that transparencies shall be mounted to standard sizes, viz: $4\frac{1}{4}$ by $3\frac{1}{4}$, half-plate, and whole-plate. That is to say, any other size than these should be mounted upon glass of the standard size next largest to itself. For instance: $3\frac{1}{2}$ by $2\frac{1}{2}$ may be mounted upon a quarter-plate cover glass; postcard size ($5\frac{1}{2}$ by $3\frac{1}{2}$), or 5 by 4, upon a half-plate; other sizes such as the Continental sizes between those given, upon glass, as stated above, of standard size just larger than themselves.

To those who would demur at rules so arbitrary as this it may be pointed out that most exhibitions insist upon standard size mounts for the pictorial prints entered; and to the objection that many Continental and other workers would not take the trouble to mount them so, and would refuse to send in to exhibitions insisting upon this rule, one can only reply that their interest and enthusiasm in their hobby could in that case be only very superficial, and their opinion of the value of such exhibitions a low one. The author prefers to think otherwise, and feels assured that the good feeling existing amongst photographers, the world over, is such that few would regard the slight extra labour involved as prohibitive, even if the benefit to their own work was nil. But indeed, it is only necessary for anyone to see the enormous improve-

ment produced, not only in his own work, but also in exhibitions of colour work as a whole, to be as enthusiastic about the innovation as the author is himself.

Method of Mounting

The method to be adopted is as follows. Suppose one intends mounting a 5 by 4 or quarter-plate transparency on a half-plate glass. First a piece of cardboard of the same thickness as the transparency should be procured, and cut to exactly the same size as the mounting glass. One of those "Jigger" knives which take used safety-razor blades is

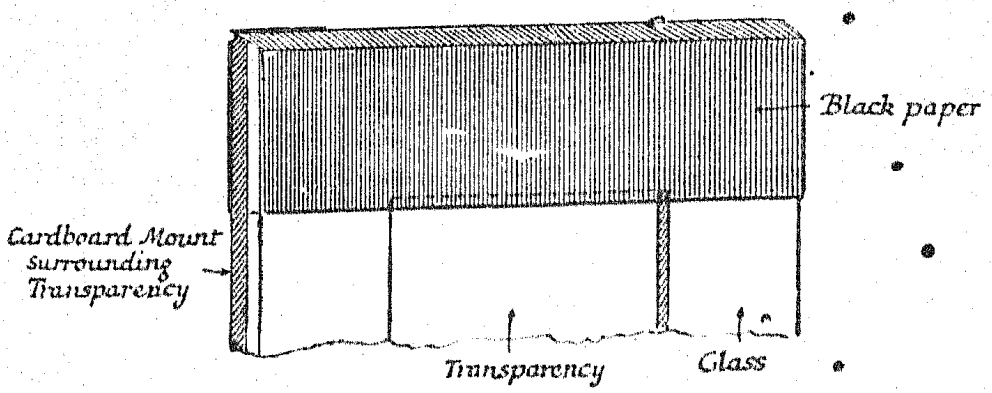


Fig. 2.—Method of Mounting Transparencies

excellent for this purpose. The transparency should then be laid on the card and placed in the position that it is thought will show it to best advantage; that is, it should be rather nearer the top than the bottom—the space at each side should, of course, be the same. A fine pencil-point is next run round the transparency, which should then be laid aside out of harm's way. The rectangle marked should now be cut cleanly out of the card. It should be remembered when dealing with large sizes that this piece will serve for mounting smaller ones and need not be thrown away. The next step is to cut four strips of black paper—that used for wrapping the Agfa plates themselves in will answer admirably. Two of these strips should be the length of the long sides, and two that

of the short sides of the mounting glass. The width should be such as will permit them to extend from about $\frac{1}{8}$ of an inch inside the edge of the transparency (so serving to keep it in place) over the face of the card, and round behind to the same position on the mounting glass. The sketch shown will illustrate what is meant.

A good photographic paste, such as the "Polywog" paste marketed by Messrs. Caribonum, Ltd., will be found excellent for the purpose of sticking the paper strips.

The paste should be well brushed into the paper, and the paper well rubbed on to the transparency and the mounting glass with a soft cloth, care being taken as before to keep the opening square and the sides parallel. Should they turn out not to be parallel when finished, they can be easily made so by cutting off the surplus with the "Jigger" when the paper is quite dry.

The front of the finished transparency should have the word "Front" printed neatly at the top in a white ink such as is prepared by Messrs. Reeves for this purpose, with the title at the bottom of the picture; while the worker's name and address should be written in a similar manner on the back.

The transparency is now ready for either viewing, or dispatching to any of the photographic exhibitions.

Artificial Light

To colour photography by artificial light the Agfa lends itself particularly well, since with it no special filter is needed for either half-watt or flashlight, if the Agfa flash powder is used. It is obviously impossible to give any but exceedingly rough estimates of the exposures, as these must necessarily differ according to light, distance of subject, colour of walls, and other data.

An example may be useful as a rough guide, and serve as a starting-point. The writer (using two 100-watt gas-filled lamps, with a white card curved behind them to act as a

reflector, and thin nainsook in front to act as a diffusing medium) found that with these lights about 6 ft. from a fruit group on an oaken sideboard, an exposure at F. 11 of 15 minutes gave a fully-exposed plate. A white card was placed on the opposite side to the lamps to act as a reflector on the shadow side. The light was placed at such a height that it fell upon the subject at an angle of about 45°, and slightly on the side of the camera.

A lens hood should always be used, or some efficient means adopted to prevent the light from the lamps shining on the lens.

Many workers are under the impression that only very frontal soft lighting may be used for colour transparency work; this is not the case. Of course the smaller latitude possessed by these plates obviously means that one cannot deal successfully with as strong a contrast as in monochrome photography, nor indeed is this desirable, but it does not follow that side lighting, producing a reasonable amount of contrast, cannot be attempted. In fact, it is only by such lighting that good modelling can be secured; the really wonderful stereoscopic effect that the colour plate is capable of producing can only be obtained with lighting of this nature.

Flashlight: Kittens and Puppies

Flashlight is another means of producing some "out of the ordinary" photographs in colour, for by flashlight such subjects as kittens and puppies and so on can be secured. Kitten photography can provide exciting sport—certainly so when as many, say, as five are attempted at once.

The plan adopted by the writer is, first of all, to open the windows of the room; this is necessary because, with the comparatively large amount of powder employed, if windows and door are shut the result may be a little alarming—not that there is any danger if only the most elementary common sense is applied to the job in hand.

A small table, just large enough to take the kiftens, should

be employed, with a suitable background some little distance behind. By a suitable background is meant one contrasting suitably with the subject, but anything violently coloured or obtrusively patterned should be avoided; also, as in other cases when colour photographs are taken, strongly coloured objects near at hand should be removed, or covered over, to avoid colour reflections. The camera should be placed in readiness on the stand, and a piece of newspaper should be placed on the table in the spot it is *hoped* the kittens will occupy, and used for focussing upon. The flash-lamp should now be got ready.

For "still life" subjects, flower studies, &c., if flashlight is employed, a makeshift arrangement of a bent up piece of tin on a pair of steps can be used for the flash-powder, which can be fired with the touch-paper supplied with it; but for any living subject a proper flash-lamp is essential, and that supplied by the Agfa Company is one of the most satisfactory the author has used. Full directions are supplied with it, and should be carefully studied before use, so that familiarity with the procedure is attained. The powder should then be mixed, care being taken not to do this near a naked light, and the smoker should put his cigarette away while any of the powder is exposed.

If the weather is at all humid the metal tray of the lamp should be warmed as a precaution against possible condensation of moisture on it, which might prevent the powder from igniting.

In measuring out the powder the amount should be put first on a piece of dry smooth paper and then shaken on to the tray; the powder should *never* on any account be poured straight out of the container on to the tray, for should the spring be accidentally released and the powder become ignited, a nasty accident might occur as the whole amount might explode.

The kittens should now be placed on the table, and the shutter of the dark slide removed—then the fun begins.

When at last the victims have assumed the desired position and attitudes, the shutter should be opened and the release of the flash-lamp pressed home, when, if your luck has been in, one of the most delightful results of which colour photography is capable will have been secured.

In exposing by flashlight care should be taken to avoid over-exposure through using too much powder; the Agfa booklet gives a table showing the approximate quantities of powder to be used according to the aperture of the lens and the distance of the lamp from the object.

THE FINLAY PROCESS

Negative Plate and Taking Screen

The Finlay process is a duplicating process. It employs a separate plate with the colour mosaic printed upon it, instead of having emulsion and colour mosaic upon the same plate, as in the combined processes. This separate plate is known as the "taking screen", and has to be put into the dark slide in front of, and in close contact with, the negative plate.

One of the fundamental necessities for success in the Finlay process, is the closest possible contact between the squares of the taking screen and the emulsion of the negative plate. For this reason the dark slides must be fitted with fairly strong springs so that the two plates are pressed tightly together. Furthermore, great care must be taken to prevent any particle of grit, or of glass (which may chip off if the plate and taking screen are forced carelessly into single metal slides) getting between them and so preventing close contact.

As with all panchromatic material it is advisable to work the Finlay negative plate in complete darkness; the plates, taking screens, dark slides, &c., should be placed in a convenient position on the table before the light is turned out.

When the negative plate is taken out of the box, it is placed with the emulsion in contact with the printed side of the taking screen, the tips of the fingers being passed lightly

down the edges to see that they are flush and parallel with one another before inserting them into the dark slide. Neglect of this precaution may make it impossible to get the subsequent lantern plate and viewing screen square with one another, and prevent the slide being put into the lantern slide box or carrier. The two are inserted in the dark slide in such a manner that the glass side of the taking screen will face the lens when in the camera.

The negative plates should always be obtained ready "backed"; the slight extra cost is well repaid by the improved quality of the negative; indeed, the author regards the use of such plates as imperative if fine results are desired.

Exposure and Development

The makers' instructions with regard to exposure and development should be carefully studied and followed. The fact that short instantaneous exposures *can* be given with this process should not be taken to imply that short exposures should be the rule, for a well-exposed plate, developed to yield a soft negative full of delicate gradations, should be aimed at; and it may be pointed out that over-exposure, provided it is not excessive, is not so disastrous with this process as with the combined ones.

Printing

After the negative has been developed, fixed, and dried, and before printing is proceeded with, the extreme edges of the emulsion should be felt with the finger-tips. If the slightest roughness or wrinkling up of the emulsion can be detected, a sharp knife should be passed round to remove them. It is essential, in order to get close contact between the negative and positive plate when in the printing frame, that anything likely to prevent this should be removed.

The printing frame should be a well-made one, with a rebate which is perfectly level all round, and with good strong springs to press the plates closely together.

If a portion only of the negative is to be printed, as for instance when a lantern slide is made from a quarter-plate negative, it is advisable to make an opaque mask of card of the same size as the negative, having an opening in it of the size proposed for the print. The mask must *not*, of course, be placed between the negative and positive plate, but beneath the negative. The purpose of this is to prevent light spreading inwards toward the centre of the picture. Although the effect of this may not be noticeable when printing from a moderately dense negative, yet with the more delicate type of negative, such as this process demands, the leakage of light inwards through the glass edges of the lantern plate will often spoil an otherwise excellent slide.

The printing frame when loaded should always be used at a standard distance from the light source, and records should be kept on the envelope in which the negative is stored, or in a separate book, of the exposure which has been found to be correct, together with the temperature of the room and solutions.

Technical Excellence

The Finlay process is capable of producing exquisite results, but only if proper care is taken to produce a really technically perfect transparency. This should be brilliant, but not *hard*; one should try to mentally visualize what is required—a positive composed of tiny squares of black, grey, and clear glass, and an exposure such that these squares are black where they should be black, grey where grey is necessary, and so on; for if one reflects it is easy to perceive how fine quality will be spoiled if this gradation is not present. If, through over-exposure, squares which should be clear glass are veiled; or if those which, to prevent unwanted colour passing, should be solid black are grey and translucent, through stopping development too soon in a vain endeavour to save the plate; the result will be a flat and uninteresting colour slide. The colours will be degraded and the slide

will be neither a credit to the process, nor be capable of giving that intense pleasure to its maker that a technically perfect colour slide will always do; and it is useless to attempt to console oneself with the reflection that perhaps if it leaves something to be desired from the point of view of technique, it looks rather more artistic because of its softness.

Softness, however, does not consist of muddiness, and the softly brilliant slide that is a joy from the artistic side is also a joy from the technical aspect, and is, if anything, rather more difficult to make than its more brilliant brother.

Step Exposures

The making of the transparency is of so much importance that the worker should be content to make haste slowly. Although at first it may seem rather tiresome to make "step" exposures for each slide, yet the slight extra trouble is well repaid, for not only is the quality of the work improved, but although one may be inclined to doubt it, the *cost* of working is reduced. Actually one wastes many more plates in the end if a sort of hit or miss style is cultivated in arriving at the correct exposure. It is very little more trouble to *begin* with a well thought out system, and careful manner of working. A careless and happy-go-lucky method is very easily got into, but very difficult to get out of. The worker will in the end find the pleasure of his work tremendously increased when he is conscious that his success is the result of care and painstaking effort instead of being merely one fortunate result among many failures. In view of the high cost of plates and screens he is apt to get discouraged, and perhaps may drop the process altogether if through waste his expenditure of material is excessive.

In making the first exposure, the printing frame should be placed at the standard distance from the light source. It will be found very convenient to have the light immediately above the printing frame. If so desired, it may be in a box so that it is screened from the rest of the room and only

shines straight down upon the printing frame, which should in this case be placed face upwards. The light is turned on, and say, 5 seconds' exposure given. Obviously this exposure must necessarily depend upon the strength of the light and the distance of the negative from it, as well as on the density of the negative. It is advisable to avoid very short exposures, which are apt to become uncontrollable. Next, a portion of the negative should be covered with an opaque card, and another 5 seconds given, followed by another, and so on, until all the negative has been exposed in strips.

The plate should then be developed according to the instructions issued by the makers. Remember again that it is never wise to expose any photographic material unnecessarily to light, however "safe" it may be presumed to be, and a piece of card should be laid over the dish during development to shield it from the direct light of the lamp.

After development is completed a short rinse in cold water should be given, followed by fixing in an acid-fixing bath. When fixed, the plate should be taken into white light and examined critically, and the strip which seems most correctly exposed noted—and that exposure given to the positive.

In case it may seem somewhat extravagant to use a whole lantern slide to find the exposure, it may be pointed out that photographic plates are easily cut with the wheel glass-cutter which may be purchased for sixpence or so in the cheap stores. The plate should be laid upon a perfectly level support, with the emulsion face down on a piece of clean paper, and a firm stroke taken with the cutter against a rule; the plate being given a sharp bend backwards and then forwards, a perfectly clean break will be made. If there should be any tendency for the emulsion to peel off, though this is most unlikely to occur, a cut may be made through the emulsion with a sharp knife opposite the cut on the glass. In this way the plate may be cut into three pieces, and this will then be found a much more economical method of procedure than trying to hit the exposure by guess-work.

Positive and Viewing Screen: Registering

Once the positive has been made, it should be dried in a position where it will be free from any chance of dust settling upon it—beneath a projecting shelf or piece of card, with the emulsion outwards, in an airy room, is perhaps the ideal. When dried, the edge should be scraped free of any projections, and then a viewing screen should be placed upon it, care being taken that the scratch to be found on the screen (if a lantern-sized one is used) is placed in the same direction as the long side of the original negative. This is necessary, since it will only register in one direction of the plate. The two plates, with the emulsion of the transparency in contact with the printed side of the viewing screen, should now be taken between the fingers and held towards the light. If this is done in daylight it is best to stand some way away from the window. The plates should now be moved against one another with a slightly circular movement, when a network of colours will appear; these will form into squares which, as the movement continues, will gradually disappear, then the slide will appear in more or less uniform colour, in all probability not in the correct colours. The plates should then be tilted slightly, first in one direction and then in another, care being taken to hold them tightly pinched together all the time; in one of these directions the correct colours will be seen. Then, since one should have the viewing screen towards one, this should be " squeezed " very gently in that direction. The amount of movement required is exceedingly small, probably about one six-hundredth of an inch, so that we can only describe the necessary movement as a " squeeze ".

Binding

As soon as correct register has been secured, the plates should be held tightly together with one hand, and a strong " Bull-dog " metal paper-clip should be clipped on one edge, and a second one on the opposite edge. Some pieces of

lantern slide binding-tape having been cut into 3¼-in. lengths, or whatever length the plates used may be, one of them should now be moistened and applied to one of the free edges, and a second strip to the other free edge; and these should be carefully and thoroughly rubbed down with a soft cloth. When they are practically dry, the clips should now be put on these two sides, and the other edges dealt with similarly.

It should be pointed out that some of the lantern slide binding strips are coated with gum which makes them quite useless for those colour slides in which the slightest after-movement will throw them out of register and destroy the colours.

The binding strips known as "The Specialist" made by Messrs. Fry, or Dennisons Lantern Slide binding-tape, will be found excellent for the purpose.

Faults and Failures

The principal causes of the faults which are liable to occur may be outlined as under.

The picture has a general blue tinge over it.—This may be due to omitting to put the compensating filter on the lens; or possibly to the filter-holder not fitting snugly on to the lens mount, and permitting white light to pass round the filter; or even to a pinhole in the camera.

Only patches of colour may be seen.—Either the taking screen, or the negative plate, if the latter is an "unbacked" one, has been put into the dark slide the wrong way round, i.e. glass to film instead of film to film. If the picture is in correct colour in parts and in the remainder not, the probable cause is that taking screen and negative were not in close contact all over at the moment of exposure. A particle of glass or dust of some kind may have got between them when they were being inserted into the slide. Care should be taken, especially with single metal slides, to avoid chipping a particle of glass off the edge when using any force against the spring

which is to be found at the bottom of many of these slides. This partially correct colour may also be due to insufficiently strong springs in the slide, or to slides of unsuitable design.

In using double-dark slides it is obviously necessary, if one side only is to be filled, to put an old plate in the other side so that the spring has something to press against.

Colour reflections.—These have to be guarded against, and care should be taken when making the exposure. (See the remarks on p. 75)

Weak colours in the finished transparency.—When the colours though correct are weak, the fault is due to one of three causes.

1. It may be due to the photograph itself being taken in very dull flat lighting. Although it is not suggested that colour photographs should only be taken in brilliant sunlight, yet there is often a tendency to forget that the actual exposure *was* made in dull light, and to expect the colours of the subject to be as brilliant and strong as they would be under better conditions. One has only to reflect upon the difference made upon a landscape by the presence of sunshine, as compared with the same view seen on a dull day, to realize the enormous difference the sunlight makes, and this consideration should be taken into account before a rather disappointing transparency is condemned.

2. It may be due to poor quality in the positive, arising from faults in the making; this *is* so often the cause that it is referred to here again, and the reader is reminded of the admonition already given regarding the making of the transparency.

3. The transparency is of correct gradation but generally too pale in colour; this is probably due to insufficient exposure of the positive, and slightly more should be given, with the same development as before. It is sometimes possible to improve matters with slight intensification, although as a general rule both intensification and reduction tend to alter the gradation and falsify the colour, and for a really fine

result it is better to make a fresh positive. If an intensifier is tried chromium intensifier is possibly the best for the purpose.

Generally false tone over the slide.—This is most probably due to the photograph having been taken under lighting conditions for which an unsuitable filter has been used. Exposures should not be made under such conditions as prevail, for instance, in a flower show that is held in a tent; nor in a green-house, the glass of which has been covered with the semi-translucent paint often used in the sunniest months of the year. As the Finlay Company do not provide a special filter for such conditions the result may be improved, if the exposure simply *must* be made, by removing the compensating filter for part of the exposure, but this can only be a rough-and-ready method of compensating for the altered conditions.

General fogginess.—This may be due to an unsafe dark-room light, or the room itself may not be light proof, or the plate may have been exposed unduly to the safe-light during the manipulations.

Concluding Remarks

In conclusion, it is the earnest hope of the author that the descriptions given of the various methods of working may not tend to produce the impression that the practice of colour photography is a tedious business. If that should be so, then failure indeed is the result of his efforts. It should be constantly remembered that operations which may take but a few seconds to perform may perhaps need a page to describe in a way which will be intelligible to one unacquainted with the procedure.

The author has indulged in this not altogether inexpensive hobby as an amateur for more than fifteen years, and having finally taken it up professionally he has not, as many of his friends predicted, found his interest in it wane. The work remains as fascinating and full of interest as ever, and that

despite the failures which occasionally still contrive to ward off monotony. It may therefore be hoped that this work will induce others to traverse the paths which have brought so much pleasure, as well as some little profit, to the author.

One final word of advice to the prospective colour worker who is not already a member of a photographic society or club. Repair the omission without delay—there is no more valuable means of maintaining and increasing one's interest in a hobby than the society of kindred spirits. The author owes much to the constant help, encouragement, and good fellowship, which it has been his lot to encounter, first in the Richmond Camera Club, and afterwards in the Royal Photographic Society. To Dr. George H. Rodman he owes even more, and what success he has attained in colour photography is largely due to his following the advice given by that genial President of the Richmond Camera Club, on the occasion of the presentation of the author's first award for a colour transparency: "Specialize in this, my boy—don't fritter away what time you have for your hobby in first this branch and then another—but if you wish to attain success, specialize."

And this advice the author would pass on to the reader of his book.

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